

Mormon Flat Dam
Salt River
Phoenix Vicinity
Maricopa County
Arizona

HAER No. AZ-14

HAER
ARIZ,
7-PHEN.V,
4-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
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AZ-14-30 Staircase leading to spillway operating deck.
Photographer Mark Durben, 1988.
Source: Salt River Project.

AZ-14-31 Spillway operating motors looking south.
Inscription on equipment reads, "U.S.B.R. 1937."
Photographer Mark Durben, 1988.
Source: Salt River Project.

AZ-14-32 Spillway operating equipment looking north.
Photographer Mark Durben, 1988.
Source: Salt River Project.

AZ-14-33 HEFU penstock and original power plant.
Photographer Mark Durben, 1988.
Source: Salt River Project.

AZ-14-34 HEFU turbine shaft.
Photographer Mark Durben, 1988.
Source: Salt River Project.

AZ-14-35 Control panels at Mormon Flat power plant.
Photographer Mark Durben, 1988.
Source: Salt River Project.

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Photographer Mark Durben, 1988.
Source: Salt River Project.

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February 12, 1968.

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HISTORIC AMERICAN ENGINEERING RECORD

Mormon Flat Dam
HAER No. AZ-14

Location: Mormon Flat Dam is located on the Salt River in eastern Maricopa County, Arizona. It is approximately 50 miles east of Phoenix. UTM coordinates 25 feet northeast of the dam (in feet) are: Easting 1505701.5184; Northing 12180405.3728, Zone 12. USGS 7.5 quad Mormon Flat Dam.

Date of Construction: 1923-1925.

Engineer: Charles C. Cragin.

Present Owner: The Salt River Project.

Present Use: Mormon Flat Dam is operated by the Salt River Project for the purposes of generating hydroelectric power and for storing approximately 57,000 acre feet of water for agricultural and urban uses.

Significance: Mormon Flat Dam was the first dam constructed under the Salt River Project's 1920's hydroelectric expansion program.

Historian: David M. Introcaso, Corporate Information Management, Salt River Project.

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Chapter One: Introduction

Like many twentieth century western cities such as Boise, Denver, El Paso, Fresno, Salt Lake, Spokane, and others, Phoenix's economic base in the nineteenth century was irrigated farming. Beginning in the late 1860s, non-Indians settled in the central Arizona desert, in which Phoenix is located, and began to construct diversion works and canals to irrigate lands adjoining both banks of the Salt River. Settlers continually extended the Salt River Valley's canal and ditch system so that by 1889,¹ approximately 35,000 acres were receiving irrigation water.

In the 1890s the Salt River Valley's economic base continued to expand as more and more land was brought under irrigation. By the end of the decade, approximately 110,000 acres were planted, mostly in forage crops and grains. However, continued expansion of the Valley's farm lands appeared doubtful, as the area of land in the Salt River Valley susceptible to irrigation far exceeded the available water supply. Consequently, by the end of the 1890s, the normal flow of the Salt, and its tributary the Verde River, had been thoroughly exploited. Competition for the limited supply resulted in an excessive number of private water companies which constructed an overly elaborate and redundant system of parallel canals. Valley-wide irrigation became grossly inefficient and future development very unlikely. Perhaps even more harmful to the Valley's irrigation network was the amount of litigation arising over

¹The following discussion is only intended to provide a brief overview of irrigation and reclamation development in the Salt River Valley. For a more complete discussion see the sources cited here and in the following notes. Earl Zarbin, "Salt River Valley Canals: 1867-1875," Paper presented to the Salt River Project, January 14, 1980, Copy available at the Salt River Project Research Archives, Tempe, Arizona; Earl Zarbin, "The Swilling Legacy," reprint, (Phoenix: The Salt River Project, 1981); U.S. Congress, House, Irrigation Near Phoenix, Arizona, Doc. 342, 54th Cong., 2d Sess., 1897, 49-55; U.S., Department of the Interior, Reclamation Service, First Annual Report of the United States Reclamation Service, (Washington: Government Printing Office, 1903), 75-79. U.S. Congress, House. Commission on Organization of the Executive Branch of the Government, Water Resources and Power, Doc. 208, 84th Cong., 1st Sess., 1955, 44; The population in Maricopa County in 1889 was 10,986. Thirteenth Census, Vol. 2, p. 71.

competition for the limited water supply. Added to these problems was abnormally dry weather which began in 1898.²

With maximum economic development nearing reality at the turn of the century, Valley farmers knew that to overcome their difficulties and to further economic growth it was vital that storage dams be built to capture flood and waste water. Valley farmers realized the need for a year-round, dependable water supply well before the deteriorating conditions of the late 1890s. In 1888, the Maricopa County Board of Supervisors solicited federal support when the Senate Special Committee on Irrigation and Reclamation of Arid Lands heard testimony in Phoenix in the fall of 1888. Phoenix leaders petitioned the Committee to have Congress loan the county money or permit it to³ issue bonds to finance construction of a storage reservoir.

Private enterprise continued to plan, however, the construction of storage dams on the Salt River and other rivers and streams in central Arizona. Dam sites were identified and investigated on the Salt, Verde, Agua Fria, Hassayampa, New and Gila rivers, and on Cave and Queen creeks. Substantial investment capital was not available in Arizona to construct large storage dams; by 1900 no works succeeded much beyond the planning stage. The cost of water storage development was enormous compared to the assessed value of Maricopa County. The cost of a Valley-wide

²Twelfth Census, Vol. 6, Agriculture, 825. From 1898 through 1904 rainfall in the Valley fell below average in six out of seven years. Irrigation Near Phoenix, Arizona, 49-53, 92-95. See map of Salt River Valley canals between pages 92 and 93.

³The Senate Special Committee on Irrigation and Reclamation of Arid Lands heard testimony on developing stored water in Arizona when it met in Phoenix in the fall of 1888. See U.S. Congress, Senate, Report of the Special Committee of the United States Senate on the Irrigation and Reclamation of Arid Lands, No. 928, 51st Cong., 1st Sess., 1890; Geoffrey P. Mawn, "Phoenix, Arizona: Central City of the Southwest," (Ph.D. dissertation, Arizona State University, 1979), 219-222; Karen Smith, The Magnificent Experiment, Building the Salt River Reclamation Project, 1890-1917, (Tucson: University of Arizona Press, 1986), 7-11.

irrigation project was estimated at \$6 million.⁴ The county's assessed value was only \$10 million.

With the Salt River Valley's agricultural development problem growing more severe and private ventures unable to make credible progress, the Valley's future was dependent upon national sponsorship of irrigation projects. Valley leaders would turn their attention to Washington D. C. because, as S. M. McCowan, Maricopa County Board of Trade Chairman, stated, Phoenixians "were too ambitious to be satisfied with conditions that [fell] short of the best possibilities."⁵

Regional efforts to petition the federal government to support western water storage projects also began in 1888. Led by Wyoming senators Francis E. Warren and Joseph M. Carey, and Nevada senators William M. Stewart and Francis G. Newlands, western lawmakers solicited Congressional support for irrigation when Senator Stewart succeeded in appropriating funds to have the U.S. Geological Survey investigate "the extent in which the arid region can be

⁴Irrigation Near Phoenix, Arizona, 62-77. Smith, The Magnificent Experiment, Building the Salt River Reclamation Project, 14. The most successful effort made was work undertaken by the Agua Fria Water and Land Company. It nearly completed a sizeable masonry diversion dam on the Agua Fria River, thirty-five miles west of Phoenix, before it went bankrupt in 1896. Under its later name, the Maricopa County Municipal Water Conservation District Number One, the diversion dam and a storage dam were eventually completed on the Agua Fria River in the 1930s. See David M. Introcaso, "The History of Water Storage Development on the Agua Fria River: The Construction of Waddell Dam," National Park Service, Historic American Engineering Record (HAER) AZ-11, 1988. Copy available at the Salt River Project Research Archives.

⁵For a discussion on the efforts made by Salt River Valley leaders, B. A. Fowler and others, to effect Congressional support, see Smith, The Magnificent Experiment, Building the Salt River Reclamation Project, 1-24; Mawn, "Phoenix, Arizona: Central City of the Southwest, 1870-1920," 219-269; Earl Zarbin, Roosevelt Dam: A History to 1911, (Phoenix, Salt River Project. 1984), 19-40; First Annual Report of the Reclamation Service, 1902, 15-75. McCowan quotation cited in Smith, The Magnificent Experiment, Building the Salt River Valley Reclamation Project, 6.

redeemed by irrigation." ⁶ Through the 1890s, these senators and their constituents petitioned Congress to do more. In 1892 they requested Congress to cede all arid lands to the western states for bonding collateral. In 1896 Senator Warren proposed that the federal government construct storage dams and turn them over to the states upon completion. All the while federal support was being solicited, Senator Warren and his western bloc maintained that the states should manage the public program.

When legislation was finally passed in 1902 for the federal construction of irrigation projects, it looked nothing like earlier efforts. Rather, it came as an aberrant proposal. The National Reclamation Act, signed by President Theodore Roosevelt in June, was completely antithetical to the tenets held by western irrigation proponents. The new law made the construction of reclamation projects purely a federal undertaking. Private enterprise would not be involved and the law left no avenue for state control. The act disallowed any intervention by the states by vesting all powers with the Secretary of the Interior. Funding the program was even beyond the purview of congressional oversight.

The man who proposed the Reclamation Act was Nevada's Senator Francis G. Newlands. In 1889 Newlands began a plan to develop an irrigation project on Nevada's Truckee River. After Newlands spent \$250,000 and two years, the project

⁶Congressional Record, 51st Cong., 1st Sess., July 18, 1890, 7410. Stewart's measure led to John Wesley Powell's irrigation survey of the West. See Everett W. Sterling, "The Powell Irrigation Survey, 1888-1893," Mississippi Valley Historical Review 27 (December, 1940), 421-434. Western legislators believed that topographical maps would provide enough information to spur private syndicates to construct irrigation works.

⁷William Lilley and Lewis L. Gould, "The Western Irrigation Movement 1878-1902: A Reappraisal," in The American West, ed. by Gene M. Gressley, (Laramie: University of Wyoming, 1966), 57-74. See also John T. Ganoe, "The Origin of a National Reclamation Policy," Mississippi Valley Historical Review, 18 (June 1931): 34-52. Ganoe argued that reclamation lobbyist, George W. Maxwell, "turned the whole thought of the irrigated West toward national reclamation," through the use of Hiram M. Chittenden's 1897 report which called for national development of irrigation works. The suggestion to cede arid lands to the western states led to the 1894 Carey Act.

failed dismally. From this experience, Newlands concluded that private investment could not reclaim the West and that the states were woefully incompetent in managing the development of irrigation projects. Therefore, Newlands phrased his legislation to exclude any possibility of state control or influence. Under Newland's bill, the Secretary of Interior was given broad authority to locate and construct irrigation projects in the sixteen western states and territories. Funding for the construction and maintenance of these projects would be obtained through the money received by the sale of public lands located therein. The money expended to develop the projects would be recovered from those farmers who benefitted from it. Repayment of the projects by users would be kept in a revolving fund to be used to support future federal reclamation works.

Whether or not the final reclamation bill was legislative legerdemain or as one historian termed, a "political fluke," it nevertheless proved tremendously significant for the farmers of the Salt River Valley. One year prior to the passage of the Reclamation Act, a federal study of water storage possibilities on the Salt River, which communities in Maricopa County helped fund, showed that the Salt River at its confluence with Tonto Creek presented an "especially favorable site" for the construction of a large storage dam.¹⁰

Favorable review of the Salt site, combined with intensive lobbying efforts by organized political leaders of the Salt

⁸Ibid., 59-62. For a complete review of the Reclamation Act, including its ten year repayment provision, see Richard K. Pelz, ed., Federal Reclamation and Related Laws Annotated, vol. 1, (Washington D.C.: Government Printing Office, 1972), 31-89; Theodore M. Schad and John Kerr Rose, Reclamation - Accomplishments and Contributions, (Washington D.C.: Library of Congress, Legislative Reference Service, December 15, 1958) 2-12; First Annual Report of the Reclamation Service, 60-75; Many of the provisions of the Reclamation Act were subsequently changed. See Pelz for the Act's revisions.

⁹See Gene Gressley's comments in his introduction to The American West, ix.

¹⁰U.S. Department of Interior, United States Geological Survey, Water Storage on Salt River, Arizona, by Arthur Powell Davis, Water Supply and Irrigation Paper No. 73, (Washington D. C. Government Printing Office, 1903), 35.

River Valley, convinced Secretary of the Interior Ethan Allen Hitchcock to select the Salt River Project in 1903 as one of the national government's first reclamation projects.¹¹

Plans to construct the Salt River Project's newly-named Roosevelt Dam were complex. The site was remote, located seventy miles from Phoenix in the Mazatzal and Sierra Ancha mountains. Extensive road building was necessary to make it accessible to freight. Also due to the location, it was necessary to construct a cement mill, since freighting the amount of cement required was cost-prohibitive. Construction required the opening of several rock and aggregate quarries, a sawmill, and a telephone line to Phoenix.¹²

To facilitate construction of Roosevelt Dam, federal engineers, working under the newly-created Reclamation Service, needed a power source to provide 1,200 horsepower to run the contractor's machinery, operate the cement mill, and provide lighting. Again, freighting expenses made fuel oil too expensive. Burning wood was not an alternative either; only a limited supply was available at the dam site. Consequently, Reclamation Service engineers planned to develop a temporary hydroelectric plant at Roosevelt. Power would be developed by constructing a diversion dam and power canal sufficiently upstream to deliver water to the dam site with an appreciable vertical drop or head of 220 feet.

¹¹Hitchcock considered three sites in Arizona: the Salt River site and two on the Gila River. For a discussion on the selection of the Salt River Project, see Karen L. Smith, "The Campaign for Water in Central Arizona, 1890-1903," Arizona and the West 23 (Summer 1981): 127-148. Hitchcock gave provisional approval of the Salt River Project on March 12, 1903. U.S. Department of the Interior, Reclamation Service, Second Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1904), 72.

¹²For accounts of Roosevelt Dam's construction which include photographs and construction drawings, see the Reclamation Service's Second Annual Report (1902-1903) through its Eleventh Annual Report (1911-1912). See also Karen L. Smith, The Magnificent Experiment, 70-91; Earl Zarbin, Roosevelt Dam, 87-240; and U.S. Department of the Interior, Reclamation Service, Salt River Project, Arizona, Final History to 1916, 3 vols. April 1, 1916, (Typewritten.)

Through this method 4,400 horsepower could be generated,¹³ more than enough to meet construction needs.

The hydroelectric and transmission technology used at Roosevelt Dam was pioneered in California in the 1890s. Because the state lacked adequate energy resources, fossil fuels and timber, and because water from the Sierra Nevadas offered a secure and cheap alternative energy source, Californians, using the crossover applications of railroad, logging, irrigation, and mining engineering, advanced the technological development of polyphase, alternating current, high voltage, long-distance hydroelectric manufacturing and transmission. Through the work of Almerian Decker, engineers at Westinghouse, General Electric, and others, hydroelectric plants were pioneered by fledgling utilities, including the San Antonio Company, the Redlands Electric Light and Power Company, the Sacramento Power and Light Company, and the Yuba Electric Power Company. The California success at adapting electrical theory to local circumstances demonstrated the economic viability of developing and transmitting hydroelectric power. It was quickly transferred to neighboring states and territories where environmental circumstances were the same.

¹³The development of hydroelectricity at the Salt River dam site had been considered in the Geological Study's 1901 study. In that investigation, Davis suggested the construction of a diversion dam and canal. U.S. Department of the Interior, Geological Survey, Water Storage on Salt River, Arizona, By A. P. Davis, Water Supply and Irrigation Paper No. 2, (Washington D.C: Government Printing Office, 1897), 45-46. James M. Gaylord, Power and Pumping System of the Salt River Project, Arizona, January 1, 1914, (Typewritten.) Copy available at the Salt River Project Research Archives. U.S. Department of the Interior, Reclamation Service, Second Annual Report of the Reclamation Service, 72-76; U.S. Department of the Interior, Reclamation Service, Third Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1905), 151-152; U.S. Department of the Interior, Reclamation Service, Fourth Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1906), 64-65. For a detailed account of the construction of the Roosevelt diversion dam and power canal, see David M. Introcaso, "The Roosevelt Power Canal and Diversion Dam, National Park Service Historic American Engineering Record (HAER), AZ-4, 1984. Copy available at the Salt River Project Research Archives.

Californian hydroelectric technology was brought to the Salt River Project by Orville Hiram Ensign, Reclamation Service Chief Electrical and Mechanical Engineer. From 1894 through 1897 Ensign had worked for the Redlands Electric Light and Power Company, which constructed the first three phase, alternating current electrical system in the United States. Applying the knowledge and experience he gained at Redlands, Ensign designed a hydroelectric system for the Salt River Project.¹⁴

To cultivate the maximum amount of acreage under the project - stored water would not be sufficient to irrigate all Project lands - the Reclamation Service realized that it could substantially enhance its irrigation plan if it supplemented stored water by using surplus hydroelectric power generated at Roosevelt to pump groundwater in the Valley.

Underground water resources were already in wide use when the Reclamation Service considered this plan. The Geological Survey found farmers using several hundred shallow and deep wells in Phoenix, Tempe, and Mesa when it conducted a detailed investigation on the groundwater supply and geology in the Salt River Valley in 1903. The Survey's report found that an "immense quantity of water" existed over the Salt River Valley's 525 square miles. Most of this water was available at less than fifty feet from the surface. Reclamation Service engineers concluded that the great volume of quality groundwater available made pumping a very prominent consideration. Hydroelectric power produced

¹⁴For a full treatment on California's development of hydroelectric generation and transmission, and the state's accomplishments in conveying three phase, high voltage, alternating current, see Thomas P. Hughes, Networks of Power, Electrification in Western Society, 1880-1930 (Baltimore: The Johns Hopkins University Press, 1983): 262-284; Harold C. Passer, The Electrical Manufacturers, 1875-1900 (Cambridge: Harvard University Press, 1953) 276-320; William A. Myers, Iron Men and Copper Wires (Glendale: Trans-Anglo Books, 1984); Edwin T. Layton, Jr., "Scientific Technology, 1845-1900: The Hydraulic Turbine and the Origins of American Industrial Research," Technology and Culture 20 (1979): 64-89. Ensign studied mechanical arts at Cornell University for two years. Beginning in 1882 he held a series of jobs for railroads and electrical companies. He joined the Reclamation Service in 1904. Concerning the Redlands plant, see "The First Three-Phase Transmission Plant in the United States," The Electrical Review 34 (February 16, 1894): 171.

at Roosevelt could draft enough underground water to irrigate an additional 50,000 acres.¹⁵

Realizing that there would be a sustained use for hydroelectricity beyond the dam's construction, the Reclamation Service changed its power plant design at Roosevelt. The original plan located the "temporary" construction generators inside the reservoir about eighty feet above the Salt River stream bed. This plan was not used. Instead, the Reclamation Service installed the power canal units immediately below the south, downstream side of the dam and housed in a cut out in the canyon wall. The equipment was placed in a shallow cave to protect it from floods and blasting. Water was conveyed to the generating units from the power canal above through a 620 foot, steel-lined penstock tunnel, seven feet in diameter. Although the diversion dam was not completed until October 1906, the first power canal unit began producing power six months earlier from water diverted into the canal by a temporary brush dam at the diversion dam site. Water from the canal produced 1,300 horsepower, more than needed to supply construction.¹⁶

¹⁵U.S. Department of Interior, Geological Survey, Underground Waters of Salt River Valley, Arizona, By Willis Thomas Lee, Water Supply and Irrigation Paper No. 136, (Washington: Government Printing Office, 1905); Alfred J. McClatchie, Irrigation at the Station Farm, 1898-1901, Arizona Agriculture Experiment Station, Bulletin No. 41, 1902; U.S. Department of Interior, Geological Survey, The Underground Waters of Gila Valley, Arizona, By Willis Thomas Lee, Water Supply and Irrigation Paper No. 104, (Washington D.C.: Government Printing Office, 1904). The Reclamation Service also considered two downstream sites, one on the Salt and one on the Verde River, as additional hydroelectric power sites. Third Annual Report of the Reclamation Service, 151-152.

¹⁶Before the power canal generated electricity, 150 horsepower was produced from a wood burning steam unit which supplied power for hoisting and aggregate processing and for the machine and carpentry shops. James M. Gaylord, Power and Pumping System of the Salt River Project, 26-33, 39-43; Final History to 1916, 113-114; U.S. Department of the Interior, Reclamation Service, Fifth Annual Report of the Reclamation Service, (Washington D. C.: Government Printing Office, 1907), 87-88; Introcaso, "The Roosevelt Power Canal and Diversion Dam," 5-18.

The "permanent" power plant at Roosevelt was begun in October 1906 and finished in the spring of 1908. After completion, the power canal units, now expanded to three, were moved into the power house through the extension of the seven foot penstock. Complementing the hydroelectric output from the power canal penstock were three additional units which received stored water from the reservoir through a ten foot diameter penstock running through the dam face. By 1912, five units were installed with an operating capacity of 4,500 kilowatts (kw). The sixth turbine, rated at 5,000 kw capacity, was installed in 1916.¹⁷

In 1906, Congress passed legislation authorizing the Secretary of Interior to sell excess hydroelectric power generated at federal reclamation projects, giving municipal purposes preference. The receipts from these power agreements would be deposited in the reclamation fund and credited as repayment money to the project from which the power was derived. The primary use for Roosevelt's hydroelectric power was to pump groundwater, however, with an anticipated excess from the Roosevelt plant, power was actually used first for commercial purposes.

In 1907, Hitchcock's successor as Secretary of the Interior, James R. Garfield, entered into an agreement to sell 1,500 kw to the locally-based Pacific Gas and Electric Company which, in turn, retailed the electricity to the City of Phoenix and over thirty Valley businesses. Power under this contract was transmitted to Pacific Gas and Electric in

¹⁷The original "temporary" power canal unit was replaced by three permanent units by June 1909. (To convert kilowatts to horsepower, divide kilowatts by .7457.) Because the Roosevelt power plant was too small to accommodate the necessary transformers and other control and distribution equipment, a transformer house, completed in 1908, was built 600 feet downstream from the power plant. Hydroelectric power was conveyed to Phoenix via a 75 mile, 45,000 volt transmission line constructed from Roosevelt to Phoenix. For a detailed description of the Roosevelt Dam power plant building and layout, the transformer house, all electrical equipment, and transmission line, see James M. Gaylord, Power and Pumping System of the Salt River Project, 21-66; U.S. Department of the Interior, Reclamation Service, Ninth Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1911), 64-65; Final History to 1916, 500-530; U.S. Department of the Interior, Reclamation Service, Salt River Project, History of the Project for the Calendar Year 1915, Salt River Project Research Archives, Tempe, Arizona, 8.

September 1909 after the Roosevelt to Phoenix transmission line was completed earlier that year. Shortly after Pacific Gas received power, hydroelectricity was transmitted to Mesa and the Gila River Indian Reservation to lift groundwater for irrigation. ¹⁸

The Reclamation Service completed Roosevelt Dam and many associated features in 1910. Beyond the project's hydroelectric plant, transmission lines and groundwater pumping stations or batteries, the project included a list of other formidable achievements. In constructing Roosevelt Dam, the largest masonry dam in the world, the Service had also built two concrete diversion dams, over a hundred miles of roads, two miles of tunnels, bridges, buildings, levees, telephone lines, and improved many miles of Valley canals which it had purchased from private companies. All these works meshed into one systematic network which provided enough water to cultivate an area approximately 191,000 acres in size. When President Theodore Roosevelt visited the Arizona Territory to dedicate the dam and officially open the Salt River Project in March 1911, the general

¹⁸Act of April 16, 1906, 34 Stat. 116. Pelz, Federal Reclamation and Related Laws Annotated, Vol. 1, 109-112. Under this act storing water for irrigation still held priority over running water to produce power. Glenn W. Brandow, Historical Documents Pertaining to Power Contracts and Agreements of the Salt River Project, Salt River Project Research Archives, Tempe, Arizona, Inventory Box 101, No. 1887, 1, 30; Ninth Annual Report of the Reclamation Service, 64-66; U.S. Department of Interior, Reclamation Service, Eight Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1910), 46-47; U.S. Department of Interior, Reclamation Service, Tenth Annual Report of the Reclamation Service, (Washington: D.C.: Government Printing Office, 1912), 67-68; Mawn, "Phoenix, Arizona, Central City of the Southwest," 336-340. For a list of businesses which received power from Pacific Gas and Electric, see James M. Gaylord, Power and Pumping System of the Salt River Project, 174-179. For a discussion on the Gila River Reservation groundwater pumping program as defined by the 1907 Sacaton contract, see David M. Introcaso, "Water Development on the Gila River: The Construction of Coolidge Dam," National Park Service HAER Report AZ-7, 1986, 36-48. Copy available at the Salt River Project Research Archives. See also, James M. Gaylord, Power and Pumping System of the Salt River Project, 186-200.

feeling of Valley residents was without doubt one of optimism and enthusiasm for the future. ¹⁹

The successful completion of Roosevelt Dam provided the Reclamation Service and the Salt River Valley Water Users' Association (Association), the organization of landowners pledged to repay the cost of the project, with the confidence to extend their vision as to what the project and Valley could become. Through 1910, the city of Phoenix and the surrounding Valley communities had continued to grow rapidly. Phoenix's population doubled between 1900 and 1910 to 11,000 residents. The Valley was developing as a frontier urban center with a variety of business interests. Copper mines, newspapers, laundries, hotels, flour mills, meat packers, machine and lumber companies, processing plants, and other businesses ancillary to agriculture continued to locate in the Valley. All required electrical power. This fact was not lost upon either the Reclamation Service or the Association. In a 1914 report, the Service wrote:

The market for the sale of power in the project and vicinity is excellent, and the transmission lines already constructed, . . . are available to serve this market. There are no competing companies in the field, and there is ²⁰no prospect of close competition in the future.

Because the production of hydroelectricity had proven its financial worth to the project by generating thousands of dollars in repayment income, the Association and the Reclamation ²¹Service looked to expand the project's power capacity.

¹⁹The dedication of Roosevelt Dam was held on March 18, 1911. Tenth Annual Report of the Reclamation Service, 64-65. The significance of Roosevelt Dam to the Territory's development is probably best seen in Arizona's state seal which depicts Roosevelt Dam.

²⁰James M. Gaylord, Power and Pumping System of the Salt River Project, 169.

²¹The Reclamation Service's Tenth Annual Report (1910-1911), stated, "Excellent progress, on the whole, has been made along all agricultural lines during the past year, and a general feeling of optimism prevails throughout the project." U.S. Department of the Interior, Reclamation Service, Tenth Annual Report of the Reclamation Service,

(Footnote Continued)

Under an agreement reached with the Reclamation Service in August 1910, the Association undertook a \$900,000 program to construct three hydroelectric plants in the Salt River Valley. Under the Reclamation Service's design specifications and supervision, the Association built three low-head hydroelectric facilities along Valley canals. The plants were: the Consolidated power plant at the junction of the South and Consolidated canals; the Arizona Falls power plant along the Arizona Canal; and the Cross Cut power plant which used falling water from the newly built Cross Cut Canal which joined the Arizona to the Grand Canal. When the Association completed these works by 1914, it turned their operation over to the Reclamation Service as part of the integrated Salt River Project. Hydroelectric receipts from these plants, along with those earned at Roosevelt, went to defray the Association's repayment obligation.²²

The total capacity of the Valley plants was approximately 8,000 kw. Combined with Roosevelt, which added a sixth unit in 1916, the Salt River Project was now producing approximately 18,000 kw of hydroelectricity. About a third of the power was sold to the Inspiration Consolidated Copper Company in Miami, east of Phoenix, and another large percentage was still being wholesaled to the Pacific Gas and Electric Company. Power also was used to pump groundwater.

(Footnote Continued)

(Washington D.C.: Government Printing Office, 1912), 68. In the Association's Board of Governor's Minutes for June 2, 1910, the Association paraphrased the Reclamation Service's A. P. Davis' comments concerning the project by stating, "Mr. Davis said that he had an especially warm feeling for this project and everything connected with it . . . because it is the largest and most spectacular thing for which the Reclamation Service is responsible." Minutes, Salt River Valley Water Users' Association Board of Governors, June 2, 1910, Book 3, 7. Mawn, "Phoenix, Arizona, Central City of the Southwest," 346-347.

²²The final cost to develop the three plants was \$1.1 million. "Contract Between the Salt River Valley Water Users' Association and the U.S. Secretary of the Interior," August 30, 1910. Copy of contract printed in the Minutes, Salt River Valley Water Users' Association, June 16, 1910, Book 3, 10-12; C. H. Fitch to Frederick H. Newell, August 31, 1911, Historical File 150.2, Salt River Project Research Archives. For a detailed discussion of the three, low-head hydroelectric units, see James M. Gaylord, Power and Pumping System of the Salt River Project, 67-112. The head at South Consolidated was 31 feet, at Arizona Falls, 19 feet, and at Cross Cut, 111 feet.

In 1915-1916, ten pumping plants drew 42,000 acre feet of water.

For federal reclamation activities in total, the power produced at the Salt River Project in 1916-1917 generated nearly two-thirds of all Reclamation Service power in the West and returned a gross income of \$495,000, or four-fifths of Reclamation's hydroelectric revenue as a credit for Salt River Project repayment.²³

With the exception of some spillway work remaining at Roosevelt and lining certain laterals, the Reclamation Service declared that the Salt River Project would be complete by the end of 1916. The Reclamation Service considered its efforts a great success. It proudly stated that Roosevelt was "one of the great reservoirs of the world." Since 1908 the Service had been supplying water to the Valley. Roosevelt's reservoir was full and all irrigation works were "in an excellent state of efficiency." Reclamation was also managing a large hydroelectric power system which it estimated could produce an annual average income of \$300,000. Having operated the project for eight years and with it essentially complete, Secretary of the Interior Franklin Lane decided to²⁴ convey the operation of the project to the Association.

As President Wilson's Interior Secretary, Lane believed that the government should not extend its paternal role beyond the construction of its reclamation projects. The Association should be made responsible for the federal

²³U.S. Department of the Interior, Reclamation Service, Fourteenth Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1915), 28-31; U.S. Department of the Interior, Reclamation Service, Fifteenth Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1916), 22-26; U.S. Department of the Interior, Reclamation Service, Sixteenth Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1917), 22-25; U.S. Department of the Interior, Reclamation Service, Salt River Project, "History of the Project for the Calendar Year 1916," Salt River Project Research Archives, 112-119; James M. Gaylord, Power and Pumping System of the Salt River Project, 179-181.

²⁴"History of the Project for the Calendar Year 1916," 143-145. Sixteenth Annual Report of the Reclamation Service, 8.

government's works, Lane thought, just as it was obligated for remitting the cost of the project. Lane's judgement, however, was not shared by the Reclamation Service. Under the direction of A. P. Davis, Reclamation believed that relinquishing authority would deny the government the receipts from the project's hydroelectric components and thereby relinquish the only security the government had to recover its expenses. Added to Davis' objection was the Association's apparent indifference to receiving control. It had never asked to acquire the project's operation. The Association also knew it was not staffed yet to operate the project. Despite the circumstances, Lane conveyed operation and maintenance of the project to the Salt River Valley Water Users' Association in September 1917.²⁵

Under the terms of the agreement, the federal government maintained title to the Salt River Project while the Water Users' Association accepted "care, operation and maintenance." In addition, and critical to the project's future, the Association also received all "profits, revenue and income" from the project's facilities. The Association also agreed finally to the project's repayment debt, which for several years it had argued vigorously was greatly excessive. The amount fixed by the agreement was \$10,279,000, three times more than originally estimated for construction of the project. Repayment under the agreement was defined under the terms of the 1914 Reclamation Extension Act which extended the Association's payment period from ten to twenty years. Other provisions included in the agreement obligated the Association to obtain the Secretary's approval if it wished to make any significant improvements to the project. Finally, the Secretary retained the discretion to terminate the agreement to protect the government's investment if the Project was not managed adequately.²⁶

²⁵Sixteenth Annual Report of the Reclamation Service, 8-9; Smith, The Magnificent Experiment, Building the Salt River Reclamation Project, 141-146; U.S. Department of the Interior, Reclamation Service, Seventeenth Annual Report of the Reclamation Service, (Washington D.C.: Government Printing Office, 1918), 8, 64-65.

²⁶"Contract Between United States of America and Salt River Valley Water Users' Association," September 6, 1917, Copy available at the Salt River Project Research Archives. The repayment debt of \$10 million equalled \$60 per acre for 191,000 acres within the project. For information on the Reclamation Extension Act, See Pelz, Federal Reclamation and (Footnote Continued)

Although the Association did not lobby Secretary Lane for the operation of the project, it was satisfied, if not pleased, to receive it. Conditions in 1917 were excellent for the Salt River Valley farmer. Roosevelt Reservoir was full and because of the war in Europe, the production of food and fiber, particularly cotton, was in great demand. All lands with irrigation rights, including those "dry" lands that obtained water rentals, were cultivated because of appreciable per acre returns. Cotton sold at \$1.35 per pound and other crops netted farmers as high as \$100 per acre profit. Combined with a booming farm economy, the project netted \$309,000 in hydroelectric receipts, mostly from the sale of power to the copper mines. The Association could not have been on a better economic footing when it received the Salt River Project.

In taking over the project, however, the Association faced two immediate problems. First, it could not employ enough qualified zanjeros (water deliverers) due to a war-imposed labor shortage. As a result, the Association had difficulty meeting water orders, particularly to areas planted in cotton due to its peak demand needs. Under the circumstances these problems were probably unavoidable. They would be remedied over time as the Association gained operational experience. A much greater problem confronted the Association, one that questioned its very nature and could not be solved through practice.²⁷

Because the Salt River Valley's irrigation demand ran almost entirely from April 1 through October 1, hydroelectric power was only available during this period. From October through March, when the irrigation demand dropped to nearly nothing, power generation fell off, accordingly since Roosevelt was not required to release water. Making electric power secondary to irrigation, therefore, limited power development to the fluctuations in irrigation demand. With these constraints on the power system, the Association realized the opportunity this presented for competition. In its first full annual report, dated 1918-1919, Association

(Footnote Continued)

Related Laws Annotated, 186-200. Concerning the project's final repayment costs, see "Proceedings of the Board of Cost Review," Corporate Secretary's Office, Salt River Project; File, 150.22 "Board of Review - Finances," Box 5011, Salt River Project Research Archives, and Smith, The Magnificent Experiment, Building the Salt River Reclamation Project, 135-141.

²⁷Ibid., 14.

General Superintendent and Chief Engineer Walter R. Elliot explained the situation as follows:

Should a competing company obtain a foot hold in this Valley, the Association would, owing to the nature of its organization, be forced into a secondary position, with the inevitable result of having the financial returns very materially interfered with. It is not necessary, however, that the Association ever be forced into that position if it will provide the quantity of power and class of service demanded. ²⁸

Realizing potential if not inevitable competition in the Valley power market, the Association knew that its hydroelectric plants were too valuable to sacrifice to the constraints of the project's irrigation system. It also knew that its power plants needed to accommodate both the water demand and the electrical demands of its shareholders. The Water Users' needed to consider remodeling the Salt River Project electrical system, if it expected hydroelectric revenue to defer an appreciable part of the Association's \$10 million federal repayment obligation. ²⁹

²⁸Ibid., 17.

²⁹For the three fiscal years 1917 to 1920 the average net annual hydroelectric power revenue from the Salt River Project was \$299,619. In those years the Water Users repaid the federal government \$203,320 annually as repayment for the cost of the Salt River Project.

Chapter Two: The Need to Expand the Association's Hydroelectric Capacity

When the Association took over operation and maintenance of the Salt River Project on November 1, 1917 it faced several problems. Although the Reclamation Service had stated officially that the project was complete in order to transfer responsibility and initiate the repayment cycle, this only meant that the work started by the government was finished. Several other intricate issues still confronted the project and its shareholders. The Association needed to add to the project's water supply because several thousand acres of dry lands were included within the boundaries of the Association's reservoir district, but excluded from project membership; they were waiting for an assured water supply. While the Association needed to provide an additional water supply to some of its lands, other, low-lying areas (approximately 10,000 acres) needed the groundwater table reduced because inadequate drainage had caused the groundwater to rise dangerously close to the surface. The Association also wanted to improve its water delivery system, particularly to areas planted in cotton. It needed to find an adequate method for disposing of waste water. And finally, the Association faced a labor shortage because of World War I.¹

Remedies to these problems were fairly simple. To provide more water to meet the irrigation demand and to relieve those areas needing drainage from the rapidly rising water table, the Association constructed thirty-eight pumping plants in 1918. To dispose of waste water, the Association, in cooperation with private landholders, constructed several inexpensive waste ditches. To deliver more water to farmers, the Association used its drainage pumps, enlarged certain canal and lateral lengths, and added an additional pump to the Highline pumping plant. Little could be done immediately to hire additional workers, particularly water

¹The Salt River Project's reservoir district boundary or its service area is defined in the Articles of Incorporation of the Salt River Valley Water Users' Association, Article IV, Section 3, see the Reclamation Service's, Second Annual Report of the Reclamation Service, 1902-1903, 77-78. Salt River Valley Water Users' Association, Annual Report, Operation and Maintenance, 1918-1919. Phoenix: Salt River Project Research Archives, 7-21. High groundwater, or subsurface water less than ten feet from the surface, can ruin a field by choking the crops' roots or by bringing salts to the surface.

deliverers or zanjeros. Through time and² training, however, the Association added to its work force.

While the Association solved these difficulties quickly, it still needed to resolve the conflict between storing water for irrigation or releasing it to generate hydroelectric power. In his 1918-1919 annual report, Walter R. Elliot wrote, "The development of electric power on this Project is a matter that must be given more and better consideration in the future than it has received in the past. Better year-round [electrical] service is demanded, for the interest of the Project." If the project hoped to increase its power sales to commercial and industrial customers, it needed to offer a more reliable product.³

What the Association needed to do, Elliot stated, was make the "supply of power . . . during the winter months, free and independent of irrigation needs."⁴ As long as the power system was subject to the irrigation demand, Elliot recommended that the Association's Board of Governors consider constructing a steam power plant at one of its Valley hydroelectric facilities to serve the winter electrical demand. He argued that the Association's electrical service during the winter months was already unsatisfactory and that the condition would become worse as the demand grew.⁵

Elliot believed that the Association needed to expand its power services to protect its significant investment in its hydroelectric system (\$4.5 million) and to control the future power market. For example, he knew that there was already a demand by owners of undeveloped lands adjacent to the Salt River Project to the east and west to acquire cheap power to fuel groundwater pumping plants. Elliot concluded that if the Association wished to protect its investment and maintain its control of the development of electrical power

²Ibid.

³The first annual report compiled by the Water Users' was written for the eleven month period November 1, 1917 to September 30, 1918. Salt River Valley Water Users' Association, History of the Salt River Project for the Period November 1, 1917 to September 30, 1918, Phoenix: Salt River Project Research Archives, 2-5. For a report on the irrigation well development plan see pages 71-82.

⁴Ibid., 15.

⁵Ibid., 16.

in central Arizona, it would have to expand. If it failed to grow, the project's operational limitations would invite competition.

In July 1920, Elliot and Association President F. M. Wilkinson left office. They were replaced by Frank A. Reid, who was elected president, and Charles C. Cragin who was elected to Elliot's office as general superintendent and chief engineer. Frank Reid was a native of Oklahoma who attended Fort Worth University in Texas. He came to Arizona in 1910 when he purchased a cattle ranch in Ash Fork in Yavapai County. Before joining the Association, Reid and Jim Cashion formed the Reid-Cashion Land and Cattle Company. Reid also had several mining interests in Maricopa County and in northern Mexico.

Charles Cragin was born in New York and was graduated from the College of Engineering of New York University in 1906. Before moving West, he worked in developing the City of New York's water supply. He played a junior role in the design and preliminary construction of the city's Ashokan Reservoir which is formed by Olive Bridge Dam. Shortly after graduation, Cragin moved to San Francisco where he was employed as a consulting water supply engineer for the Oakland, Berkeley, and Alameda Water District. Prior to coming to the Salt River Project, Cragin also worked in British Columbia, Montana, the Dakotas, New Mexico, and many other cities in California. Under the leadership of Reid and Cragin, the Association undertook a comprehensive, two-year study to evaluate expanding the Association's hydroelectric output.

⁶For the three fiscal years 1917 to 1920 the average net annual hydroelectric power revenue from the Salt River Project was \$299,619. In those years the Water Users repaid the federal government \$203,320 annually as repayment for the cost of the Salt River Project.

⁷Salt River Water Users' Association, Annual Report, October 1, 1919 to September 30, 1920, Phoenix: Salt River Project Research Archives, 11. Reid was born in 1880 and Cragin's birth date is unknown. The present Maricopa County town of Cashion is named after Reid's partner. For biographical information on Reid, see his obituary in The Phoenix Gazette, October 24, 1961, 43. For biographical information on Cragin, see the El Paso Herald Post, January 12, 1955 and October 8, 1962. Interview with George Cragin, Charles Cragin's son, El Paso, Texas, October 19, 1988. See also the McClintock Newspaper Clipping File, item 5-I,

(Footnote Continued)

A detailed study, titled, "Report on Proposed Additional Hydro-Electric Power Development of the Salt River," was completed in February 1922 by Cragin, Assistant Chief Engineer Francis J. O'Hara, and Electrical Engineer Harry J. Lawson. The Cragin report, as it became known, answered four questions: 1) how much power could be developed economically by assessing the project's available water supply?; 2) what construction plan would develop additional hydroelectricity?; 3) what methods of financing were available for expansion?; and 4) finally, and most importantly, why was hydroelectric expansion necessary? ⁸

Cragin and his associates began their study by calculating the project's total water supply. The Association drew water from four sources: the Salt River; the unregulated flow of the Verde River; the return water at Joint Head Dam on the Salt River; and pumped groundwater. For the period of record 1899-1921, the average annual run-off from the Salt River was 882,000 acre feet. The average annual run-off from the Verde River for the period 1889 to 1921 was 594,000 acre feet. Through Joint Head Dam, a diversion structure in Phoenix which captured percolating underground water, 65,000 acre feet could be counted on annually. Groundwater pumps supplied 55,000 acre feet for the period 1919-1921; however, with the Association's newly added drainage pumps, 150,000 acre feet could be tapped annually. All totaled, the project could count on 1.69 million acre feet annually. Although Cragin, O'Hara, and Lawson showed that the project developed an appreciable amount of water, they also showed that without the ability to better

(Footnote Continued)

Phoenix Public Library, Phoenix, Arizona. Olive Bridge Dam was part of the Catskills Aqueduct and completed in 1916.

⁸C. C. Cragin, F. J. O'Hara, and H. J. Lawson, "Report on Proposed Additional Hydro-Electric Power Development of the Salt River," February 1923. Copy available at the Salt River Project Research Archives. The report cost \$30,000 to prepare. See also, Charles C. Cragin, "Development of Hydro-Electric Power As An Aid to Irrigation," Proceedings of the American Society of Civil Engineers 58 (April 1932): 545-557. Francis Joseph O'Hara was graduated from Notre Dame University in 1899 with a degree in civil engineering. After service in the military and employment for various railroads, O'Hara worked for Cragin in San Francisco in the firm Dockweiler and Cragin, Consulting Engineers. After serving in the military during World War I, O'Hara was hired again by Cragin for the Salt River Project in June 1920.

manipulate or manage its use, additional hydroelectric power was not possible.

Three operational conditions hampered expansion. Roosevelt Dam could generate power only when the irrigation demand required the release of water. This made power generation strictly a seasonal activity. Secondly, power production was even more restricted because all other project water sources were used before Roosevelt to satisfy the irrigation demand. Water from Roosevelt was released only when the Valley irrigation demand was not met by the unregulated flow of the Verde, the Joint Head flow, the normal pump supply of the Association, or possible flood water. Also affecting the production of Salt River hydroelectricity was the great variation in the river's annual flow. In 1916, 2.3 million acre feet came down the river; in 1903, only 250,000. The Salt's monthly variation could produce 100,000 acre feet for each of eight consecutive months and then produce almost no water at all.¹⁰

The Association needed more ability to regulate the flow of the Salt River than Roosevelt Dam provided. But the Association could not offset the project's irrigation demand simply to sell power. Cragin therefore concluded that the Association needed to further regulate or stabilize the Salt River's flow if the Association expected to develop a constant year-round power supply.

The Cragin report recommended four alternatives to improve the Association's power output. It restated Elliot's suggestion to construct a steam plant. The three engineers also proposed that the Association build a detention or regulatory dam below Roosevelt at the Mormon Flat site, and build another dam between the two to be used strictly for hydroelectric power production. As a third alternative, Cragin recommended that a storage dam be built on the Verde River. This would allow Roosevelt to release water in the winter for power. In the summer the Verde would release its winter storage and still permit Roosevelt to release water for power, although at a reduced rate. Cragin recommended a combination of all alternatives as a fourth possibility.¹¹

⁹Cragin, et. al., "Report on Proposed Additional Hydro-Electric Power Development of the Salt River," 2-8, 54-63. See also hydrograph number one at the end of the report.

¹⁰Ibid., 63-68.

¹¹Ibid., 8.

Cragin and his collaborators strongly recommended the second alternative. If the Association undertook the construction of Mormon Flat Dam, it could permit Roosevelt to produce hydroelectric power when there was no irrigation draft required. Mormon Flat would store 90,000 acre feet of water run for power from Roosevelt. It would also capture water from an additional 276 square mile watershed or about 30,000 acre feet more annually. The construction of the Mormon Flat Power Dam (what would become Horse Mesa Dam), approximately midway between Roosevelt and Mormon Flat, would permit the development of 25,000 kw. Cragin also recommended that power output at Roosevelt could be increased by raising its spillways fifteen feet. This would allow for 270,000 acre feet of additional water storage which would permit adding a seventh 9,000 kw unit to the dam's power plant. ¹²

Cragin estimated that the hydroelectric expansion program would cost \$5.9 million or \$175 per kilowatt. To finance the expense, the engineers recommended that the Association first consider soliciting construction funds in advance from large electrical users. Cragin estimated that among the copper companies, Central Arizona Light and Power Company (CALAPCO), and irrigation and electrical districts, there existed a demand of 60,000 kw. If these businesses funded construction, the Association could repay them through a credit and reduced rate formula. One reason Cragin argued for soliciting "up-front" funding was because he thought it would take too long to sell the expansion to the Project's shareholders who were required to approve the issuance of bonds by a three-fourths vote. He wrote, "a number of years of education would be required to convince our 5,000 shareholders of the feasibility, necessity and benefits under an ordinary bond issue method of financing." If assistance to fund construction could not be obtained,

¹²Ibid., 16-33. The report also listed several further considerations in expanding the project's hydroelectric facilities. Instead of erecting a Mormon Flat Power Dam, Cragin offered a plan to build a smaller structure at that site and build another dam at Pine Creek, seven miles below Roosevelt. Combined, these dams would produce a total of 24,000 kilowatts. Cragin offered this alternative because, although it would cost more than the one power dam, the initial expense would be lower if only one was constructed first. Cragin also suggested the construction of a power canal to run eighteen miles from a diversion structure built on the Salt to the Verde River. Salt River water would be stored on the Verde and run to produce power when the irrigation demand required.

Cragin believed that the Association¹³ had the means itself to finance the 34,000 kw development.

How the Association could expand its hydroelectric capacity, however, did not explain why it should. Here, Cragin and his associates echoed Elliot's warning and argued that the Association needed to expand the project to protect the \$4.5 million investment in its power system. However, Cragin saw other reasons for expansion. The Association needed to reaffirm its power rights on the Salt River. The report argued that Association rights to the Salt's hydroelectric potential would not be secure for more than a reasonable number of years. Failure to develop the river would risk not only losing potential future power resources, but also risk losing control of it to the Paradise Verde Irrigation District, the Roosevelt Water Conservation District, and the Roosevelt Irrigation District, organizations outside the Project's boundaries that had plans to¹⁴ develop further the Salt River Valley's water resources.

The Cragin report also considered market competition. Three potentially competitive hydroelectric projects were being planned in the early 1920s. Above Roosevelt Dam, private interests were designing the Black River Project. This development seemed unlikely from an economic standpoint. The cost per kilowatt was probably twice that of the Salt River Project's expansion plan. The Paradise Verde Irrigation District's hydroelectric development plans on the Verde River also were significantly more expensive than on the Salt. Simply, if the cost of the Verde development was competitive, the report stated that the power output from both rivers could be easily absorbed by the Valley market.¹⁵

¹³Ibid., 40-42, 53. The \$5.9 million cost included \$1.079 million for Mormon Flat, \$2.957 million for the Mormon Flat Power Dam, \$492,000 for work at Roosevelt, \$422,000 for transmission and substation improvements, and twenty percent, or \$990,000, for contingency fees.

¹⁴Ibid., 41, 70-72.

¹⁵See File, "Leg., 8-1, 1920-1923, Federal Legislation and Regulations, FPC Hearings re: Frank Baum's Black River Power Development," Box 219-37, Records Management Division, Salt River Project. The Paradise Verde Irrigation District planned to irrigate 100,000 acres north of Phoenix. The plan did not succeed. Ibid., 42-44.

Perhaps the largest power plan was the speculative development of the Colorado River by California interests. Cragin did not fear this plan either, because power off the Colorado would have to travel too great a distance to serve a widely-scattered Arizona market. He estimated the cost of developing power on the Colorado at \$155 per kilowatt. Combined with high transmission costs to serve the dispersed Arizona users, the total price of Colorado River hydroelectricity would be \$295 per kilowatt, or over \$100 more per kilowatt than what the Association could develop.¹⁶

The lack of other cheap hydroelectric power seemed to leave central Arizona's power market open to the Association. Market place conditions could not have been more favorable. In 1920 the state of Arizona used approximately 500 million kilowatt-hours of electricity with the anticipation that the annual demand would double in ten years. About eighty percent of the 1920 load was within a 100 mile radius of the Salt River Project's hydroelectric plants. Since an overwhelming amount of the state's demand was concentrated in and around the Project's electrical service area, Cragin realized that the Association had an opportunity to contribute more to the state's power demand beyond its current¹⁷ sixty to eighty million kilowatt-hour annual share.

¹⁶Ibid., 44-51. In the report, Cragin stated that A. P. Davis estimated the cost of the Colorado River project, or the Boulder Dam (now, Hoover Dam) project, would be \$55 million. The amount of power estimated would be approximately 400,000 kw. Cragin thought that large amount of power would be more appropriately transmitted to Los Angeles, Salt Lake, Denver or San Francisco, cities where there was a larger and more concentrated electrical market. In computing the transmission of Colorado River hydroelectric power to Arizona markets, Cragin excluded the outlying communities of Clifton, Morenci, Kingman, and Yuma. He thought the only competitive Colorado development was the Girard Project at Diamond Creek. However, he did not think it would compete with the Association's and that it would take a prolonged period to develop.

¹⁷Ibid., 47-48. Between 1917 and 1922 the Association produced between 60 and 85 million kilowatt-hours annually. See power system chapters in Annual Reports for years 1917-1918, 1919-1920, 1920-1921, and 1921-1922; C. C. Cragin to the President and Board of Governors, Salt River Valley Water Users' Association, in Minutes, Board of Governors, Salt River Valley Water Users' Association, November 15,
(Footnote Continued)

The Cragin report provided the Association with the technical data required to evaluate expanding its hydroelectric capacity. It explained and assessed many of the factors and circumstances to be considered. The report was very persuasive, arguing for further development. However, while the study was being prepared, financial circumstances changed radically for the Association.

Beginning in 1915 and continuing through the early 1920s, Association farmers planted more and more acres in cotton. World War I had put the fiber in great demand. In 1914 the Salt River Project had 2,100 acres planted in long and short staple cotton. By the end of the decade, 146,000 acres, or two thirds of the project's acreage, were producing cotton. The production of the fiber became so wide spread that Valley farmers plowed under alfalfa fields and slaughtered cattle to make more land available for the crop. Wartime demand rocketed cotton's price. The profit Valley farmers could make on cotton was unprecedented. For example, cotton seed returned an average per acre value of \$21 in 1917. Two years later, in 1919, cotton seed's value had risen ten fold to \$210.¹⁸

In November 1918 the war ended. Soon after peace, however, the American farming market collapsed. The artificially high demand for farming goods was over and as a result, the market soon became oversupplied. The failure of the farming economy was particularly hard-felt in central Arizona, because the end of the war meant the end of the cotton boom. Having allocated nearly all of their acreage to cotton, Association farmers could not quickly readapt to the changed farming market. After reaching record per pound return in 1919, cotton seed plummeted in 1920 to \$4.50 per acre. In 1920 an Association farmer could produce about 250 pounds of

(Footnote Continued)

1922. Copy of letter available at the Salt River Project Research Archives.

¹⁸ Salt River Valley Water Users' Crop Reports, 1914-1915, 1915-1916, 1916-1917, 1917-1918, 1918-1919. Copies are available at the Salt River Project Research Archives. Salt River Valley Water Users' Association, History of the Salt River Project For the Period October 1, 1919 to September 30, 1920, Phoenix: Salt River Project Research Archives, 9-10, 14-F; Salt River Valley Water Users' Association, History of the Salt River Project For the Period October 1, 1920 to September 30, 1921, Phoenix: Salt River Project Research Archives, 10-12. The price of cotton during the war peaked at approximately \$1.25 per pound. Its value in 1988 was approximately \$.65 per pound.

long staple cotton per acre. After raising, picking and ginning, the cost of the acre yield equaled \$150. The farmer, however, could only sell the crop at approximately \$.30 per pound or \$75¹⁹ per acre. This return amounted to only half his costs.

Other circumstances worsened the Association's financial situation. The cessation of the wartime economy also brought a decline, though less dramatic, in the copper industry. This meant a drop in income for the Association because the copper mines were its largest customers of hydroelectricity. Revenue received from Inspiration Copper Company, the largest user of hydroelectricity, dropped by nearly a third from 1920 to 1921. Also affecting the Association's prosperity was a severe summer drought. This caused local stockmen difficulty in purchasing adequate supplies of winter feed.²⁰

Beyond the effect the farming collapse had on the individual farmer, the Association became very worried that it would not have sufficient revenue to meet its annual assessment to the federal government. Under the 1917 agreement, the Association was required to pay \$203,320 annually to remit the government's expenses in the construction of the Salt River Project. Due to the nearly ruinous post-war economic conditions, Frank Reid did not think the Association would have the funds to meet its December 1, 1920 installment deadline. On November 13, 1920, Reid wrote Director of the Reclamation Service A. P. Davis that the Association had collected only \$181,000, less than half its assessments which were due on September 1. Reid also stated that since the Valley banks had depleted most of their resources in financing eighty percent of the 1919-1920 crop, and since

¹⁹The nation's wholesale price index for farm products dropped ninety points from 1920 to 1921 or from 211 to 121. The wholesale price index for farm products was given a value of 100 for the price of farm goods for the period 1910 to 1914. Richard B. Morris, ed., Encyclopaedia of American History, 6th ed, (New York: Harper and Row, 1982): 693-694; History of the Salt River Project For the Period October 1, 1920 to September 30, 1921, 11.

²⁰History of the Salt River Project For the Period October 1, 1919 to September 30, 1920, 171; History of the Salt River Project for the Period, October 1, 1920 to September 30, 1921, 10-12, 257-258. Association revenue from Inspiration in 1919-1920 was \$170,130. In 1920-1921 it fell off to \$121,567. The 1920 drought caused Association farmers to pump to 93,000 acre feet in 1920-1921.

the banks had not received an appreciable return from their loans, they were not able to provide further resources to fund the Association's 1920 repayment obligation. Reid wrote,

The condition in this valley, I do not presume, is any different from the prevailing condition throughout the United States at the present time; there being no market for any farm products other than the necessities. This condition does not give the shareholders of this valley sufficient funds to meet their obligations to the Association; and as stated before the banks having practically used up all their resources in the financing of the present crop are not in a position to make further advances, hence our condition. ²¹

Reid was able to convince the Reclamation Service to allow the Association until March 1, 1921 to make its December 1, 1920 payment. Although Davis permitted the extension, he did not understand how the Association did not have the resources to make payment. Davis knew that although the Association may not have collected its acreage assessments, it had received its electrical revenues. He believed the Association could meet the repayment schedule using its power income alone, which amounted to \$356,000 for the year ending September 30. Davis granted the delay, but maintained that the Association be assessed a ²²penalty of one percent per month for the three month period.

²¹See Part IV of the 1917 agreement between the United States and the Association. Frank A. Reid to A. P. Davis, November 13, 1922, Record Group 115, Records of the U.S. Bureau of Reclamation, General Administration and Project Records, 1919-1929, National Archives, Washington D.C. Copy available at the Salt River Project Research Archives. Additional correspondence regarding the repayment issue is contained in this record file. A copy of the file is available at the Salt River Project Research Archives.

²²Telegram to the Association from A. P. Davis, November 21, 1920; Morris Bien, Assistant Director, Reclamation Service to F. A. Reid, November 27, 1920; F. A. Reid to Morris Bien, February 19, 1921; and A. P. Davis to the Secretary of the Interior John B. Payne, February 19, 1921, Record Group 115, Records of the U.S. Bureau of Reclamation, General Administration and Project Records, 1919-1929. See also History of the Salt River Project For the Period October 1, 1919 to September 20, 1920, 172. The
(Footnote Continued)

Between November and March 1921, the farm market had not improved. Consequently, Reid asked for another extension, this time until November 1, 1921. The Association president argued that power revenues were needed to meet the project's operation and maintenance expenses and therefore were not sufficient to cover both costs. The Association had needed to spend money to repair flood damage and to develop further its groundwater drainage program. Again, Davis approved the extension with the penalty provision.²³

The Association did not make its payment when November 1 arrived. In December, Reid wrote Secretary of the Interior Albert B. Fall, explaining that again the majority of the Association membership had not been able to pay their assessments. Approximately \$380,000 in Association assessments were past due. In addition, the 1920 and 1921 cotton crops had been only partially sold and Valley banks had again lent to their limits. Reid stated that if the Association was given a third extension, until December 1, 1922, it would be able to meet its payment obligations. If the federal government did not permit another delay, Reid stated that sixty percent of the Association's farmers would be unable²⁴ to farm and 120,000 acres would have to lay fallow.

(Footnote Continued)

one percent penalty for the extension was provided for in Section Six of the 1914 Reclamation Extension Act. See Pelz, Federal Reclamation and Related Laws Annotated, 188.

²³A. P. Davis to John B. Payne, February 19, 1921, Record Group 115, General Administration and Project Records, 1919-1929. During the winter of 1919-1920, flooding caused \$84,000 damage to the south haunch of Roosevelt Dam. By 1921 drainage had become a very serious problem. About 5,000 acres had become entirely unproductive and another 60,000 acres were quickly becoming waterlogged. See drainage reports in the 1919-1920 History of the Salt River Project beginning on page 100 and in the 1920-1921 History of the Salt River Project beginning on page 95.

²⁴In his letter to Secretary Fall, Reid first claimed that the Association did not make payment on December 1, 1921 because it had been granted an extension until December 1922 in a letter written from Fall to A. P. Davis on May 18, 1921. Reid's assumption was false. F. A. Reid to Albert B. Fall, December 17, 1921; and E. C. Finney to F. A. Reid, January 6, 1922, Record Group 115, General Administration and Project Records, 1919-1929.

When Davis received Reid's petition for a third delay, his patience ended. For over a year Davis believed that despite the Association's very sick farm income, it received enough money from its power receipts alone to meet its federal debt. In November, the Reclamation Service had two consultants examine the Salt River Project's financial condition. The consultants reported that the the Valley farmers had the means to pay their assessments and that the Association had the funds to make its repayment installments. The conclusions of this report, combined with his previous belief, led Davis to think that the Reclamation Service should consider withholding water from the Association. Davis wrote that there was,

no basis for recommending to the Secretary that he should further delay action looking to the withholding of water supply to delinquent water-users on the Salt River Project unless substantial payments are made, equal at least to the amount due December 1, 1920 and accrued penalties.²⁵

In a lengthy letter to Davis written in early January 1922, Reid refuted the consultants' financial evaluation of the project. Reid explained in greater detail the Association's plight. Valley banks were carrying \$14 million in crop investments from 1919 to the present. The Association still needed to expend significant resources to remedy drainage problems and repair winter flooding damage. Concerning the Association's power revenue, Reid stated that the actual revenue from hydroelectric sales, after repaying monies advanced for the construction of the Chandler Power Plant, and for operation, maintenance, and transmission upgrades, was actually only \$372,000, much less than the \$455,000 the Association owed for two installments plus penalties.²⁶

²⁵The Association's power receipts for 1920-1921 equaled \$336,000. History of the Salt River Project For the Period October 1, 1920 to September 30, 1921, 255. L. N. McClellan and Walter Ward, "Report on Examination Salt River Project - Arizona," November 5, 1921, 1-6; and A. P. Davis to F. A. Reid, December 30, 1921, Record Group 115, General Administration and Project Records, 1919-1929.

²⁶Reid estimated Valley flooding damage for 1919 and 1921 at \$1.816 million. Reid also made his case by arguing that over fifty percent of Maricopa County residents were in arrears in paying their county taxes for 1920 and 1921. F. A. Reid to A. P. Davis, January 9, 1922, Record Group 115, General Administration and Project Records, 1919-1929.

Despite Reid's impassioned plea, the Reclamation Service still believed that the Association could make payment. It remained unconvinced that power revenues were not significant enough to cover the Association debt. It also remained unconvinced that Valley farmers could not make money raising cotton. And finally, the Service believed that if the Association's financial condition was as poor as it argued, than it should have deferred some of its \$783,000 construction expenses²⁷ over the past two years to pay the federal government.

Whether the Association had sufficient funds to pay its annual installments was clearly a matter of opinion. Davis thought the Association could if it made repayment a priority. Reid and the Association thought drainage and flood damage repair more important than meeting the federal debt. Regardless, the Reclamation Service and the Association reached an agreement concerning repayment in July 1922.

Under the terms of the 1922 contract, the Association agreed to meet specific repayment deadlines for 1922 and 1923. It also agreed to assign all power revenues to the repayment charges until those fees had been collected. After the repayment amount had been collected, the Association could use its power receipts for its own purposes for that year. If the Association was delinquent in its repayment after thirty days, the United States had the right²⁸ to take possession of the project's power plants.

²⁷Consultant McClellan computed total gross revenue for Association net power receipts from 1919 to 1921 at \$702,000. This was more than enough to pay the Association's delinquent installments. For Association construction expenses, see document titled "Construction 1919-1920 and 1920-1921" attached to Reid's February 15, 1922 letter. Memorandum from the Chief Engineer, Reclamation Service to L. N. McClellan, February 15, 1922; and Walter Ward to the Chief Engineer, Reclamation Service, February 24, 1922, Record Group 115, General Administration and Project Records, 1919-1929.

²⁸"Contract Between United States and Salt River Valley Water Users Association, Supplementary to Certain Contracts Dated Respectively, June 25, 1904 and September 6, 1917," Record Group 115, General Administration and Project Records, 1919-1929. The July 1922 contract was the result of a conference held at Secretary Fall's office on June 23,
(Footnote Continued)

The July 1922 contract included one other provision important to the Association. Under section fifteen, Secretary Fall approved the Association's hydroelectric expansion program. The Cragin report had been presented to the Secretary on June 23 when the Association, the Reclamation Service, and the Bureau of Indian Affairs met to discuss conditions generally in the Salt River Valley. The contract gave preliminary approval for hydroelectric expansion with final approval contingent upon the Service's favorable review of the Association's specific construction plans. By this time, Cragin and Reid had rejected financing the plan through advance payments, opting instead for the Association to issue bonds for the amount required.²⁹

Having rescheduled the repayment debt to the United States and secured Secretarial authority to expand, all Reid and Cragin needed to do was obtain Association Board of Governors' approval. Convincing the Board was not difficult because prosperity had returned momentarily to the Valley in 1922. The project produced its greatest power income in its history that year. The Association generated 85 million kilowatt hours of electricity which returned \$447,059 in net power revenues. This exceeded the previous record by over \$100,000. Farming wealth also returned to the Valley. The 1921-1922 crop gross value was \$15.5 million or nearly fifty percent higher than the previous year. The Association also collected \$445,000 in acreage assessments.³⁰

(Footnote Continued)

1922. A. P. Davis to Albert Fall, June 24, 1922, Record Group 115, General Administration and Project Records, 1919-1921. The July contract was preceded by federal legislation passed in March 1922 which gave water users on federal irrigation projects a two year delay in meeting their construction repayment charges. See the March 31, 1922 Act titled, "Relief To Water Users," (42 Stat 489), in Pelz, Federal Reclamation and Related Laws Annotated, 293. Under the terms of the July contract, the Association was to assign all power revenues to the annual repayment installments until all federal construction costs for the Salt River Project had been repaid. The contract also concerned issues regarding water and power for the Salt River Indian Reservation.

²⁹Ibid. Under the 1917 agreement, the Association needed to obtain the Secretary of the Interior's approval if it planned to add significantly to the project's system.

³⁰Gross farming income for 1920-1921 was \$11,435,384. Salt River Valley Water Users Association, History of the
(Footnote Continued)

In November 1922, Cragin and Reid formally took their cause to the Board. Both men argued only for the construction of Mormon Flat Dam and improvements to Roosevelt, probably because they were not certain the Board would approve issuing debt for the entire \$5.9 million plan at once. Given the recent shaky financial situation, this was not surprising. Cragin reminded the Board that the power system in its present state varied in output from 3,000 kw to 18,000 kw in wet years, and 2,500 to 7,000 kw in dry years. This widely fluctuating load operated at a reduced rate because of its variance and, Cragin stated, it was "an invitation to disastrous competition from any other power company with a more stable commodity to sell." Cragin again made the point that the Association's \$4.5 million investment needed to be protected. If the Association made the \$1.8 million recommended additions to Roosevelt and constructed Mormon Flat Dam, which he promised could be accomplished in twelve months, an additional 55 million kilowatt hours of hydroelectricity above the present output would be generated. Within a few years the increased power output made available would "operate the entire Salt River Project", pay interest on the bonds issued to fund the construction, pay the U.S. its installments, and provide \$50,000 per year for project improvements. After the federal debt had been retired in 1936, Cragin estimated that power revenue would pay all project expenses and produce a surplus, above depreciation, of over \$400,000 per year. If the Association failed to expand, Cragin warned the board that "the present strategic position of the Association with respect to [the] Arizona market is doomed" ³¹

Reid completely supported Cragin's assertions. He also stated that an expanded power system would substantially reduce water fees. Assessments would not exceed \$1.27 per acre per year, considerably less than all previous fees, which were as high as \$4.00 per acre per year. Beyond the added income, Reid claimed that water developed through Mormon Flat Dam would permit cultivating an additional 8,000 acres within the project. In summary, Reid stated,

I cannot emphasize too much . . . Mr. Cragin's report. We are in the power business [emphasis added]. We cannot afford to stay out of the

(Footnote Continued)

Salt River Project For the Period October 1, 1921 to September 30, 1922, 9, 16, 24, 227-228, 231-232.

³¹ Minutes, Board of Governors of the Salt River Valley Water Users' Association, November 15, 1922. Cragin stated that his income estimates were conservative.

power business with the large and growing demand for pumping on our project and power needs on the farm. Never in the history of the Valley has there been greater need for vision on the part of the members of the council and Board of Governors to see this great opportunity of our Association. ³²

With Reid's support, the Association Board of Governors unanimously resolved to support Charles Cragin's hydroelectric expansion plan which it called Mormon Flat Development No. 1. Under the resolution, the Board planned for a special election of the Association shareholders to vote on issuing \$1.8 million in bonds to fund the construction of Mormon Flat Dam and the recommended improvements to Roosevelt Dam. The conclusions Cragin reached in his hydroexpansion development study were nearing implementation. ³³

³²F. A. Reid to the Members of the Council, Salt River Valley Water Users' Association, November 16, 1922, Research File 480.1, Salt River Project Research Archives.

³³The resolution called for a bond issue of \$1.8 million at six percent interest repayable in 15 to 25 years. Minutes, Board of Governors of the Salt River Valley Water Users' Association, November 15, 1922.

Chapter Three: The Construction of Mormon Flat Dam

After winning the Association Board's endorsement of the Mormon Flat plan in November 1922, Reid and Cragin campaigned vigorously to sell the development to the Association farmers. This they did primarily through The Associated Arizona Producer. First published in March 1922, The Producer's purpose was to promote agricultural development in the Salt River Valley. The bimonthly tabloid was established, in part, by the Association and was distributed free to all its shareholders. Through December and January, the periodical ran a series of lengthy, front page articles selling the hydroelectric expansion plan to the Association's shareholders.

Under an article entitled, "The Mormon Flat Development Plan and Its Possibilities," published December 1, 1922, editors of the The Producer stated there was no recently planned development of resources in central Arizona that "equalled in importance, feasibility and practicality" the Mormon Flat project. The article reiterated the reasons Reid and Cragin used to win the Board's approval: the construction of Mormon Flat Dam would provide "continuous generation of power at Roosevelt throughout the entire year" by eliminating the wide fluctuation in power production in the winter months. Income generated from the increased capacity at Roosevelt, estimated at fifty million kilowatt hours, would nearly triple annual gross power revenues to one million dollars. The additional revenue would pay the Association's federal debt, all project operation and maintenance costs, the interest on the construction bonds, and eventually the bonds' principal. Construction of the dam would also provide a faster water delivery time to the Granite Reef Diversion Dam. Finally, Mormon Flat would capture water from an additional 350 mile watershed. Ninety thousand acre feet developed at Mormon Flat, along with 250,000 developed at Roosevelt, would irrigate an additional 8,000 acres of Association dry lands. The editors confidently stated, "In

¹In its first issue, March 15, 1922, The Producer was listed as the official organ of the Arizona Pima Cotton Growers, the Salt River Valley Water Users' Association, the Arizona State Farm Bureau, the Arizona Grain Growers, the Roosevelt Hay Growers, the Arizona Dairy Producers, the Arizona Poultry Producers, the office of the County Farm Agent, the Maricopa County Poultry Association, and the Union of Melon Growers. By the end of 1923 the publication's office moved to the basement of the Association's office in Phoenix and the Association took primary responsibility for the tabloid.

the construction of the Mormon Flat dam shareholders of the Salt River Valley Water Users' association [sic] are [would be] doing merely what is the logical and consistent thing for them to do." ²

Appearing under the title, "Salt River Valley Farmers Have Store of Gold in Lake," in its December 15 issue, The Producer heralded, "More than \$400,000 a year profit! Four hundred thousand dollars a year profit from the blue waters of Roosevelt lake. This is the Mormon flat development in a nutshell." The only cost to the Association, the editors argued, would be "the time taken to go to the polls and vote for it on January 4." Although the cost for the construction of Mormon Flat and the improvements to Roosevelt was estimated at \$1.8 million, the article again detailed how the additional revenue from increased power sales at Roosevelt would pay the cost of the development and reduce the shareholder's acreage assessments to "not more than \$1.30 per acre," or even possibly "wipe out water assessments completely." Therefore, the only cost to the shareholder would be the time to vote. ³

In the last issue appearing before the bond election, Louis C. Hill, engineering consultant for the Association and former Reclamation Service supervising engineer for the construction of Roosevelt, authored a Producer article titled, "Financial Aspects of Salt River Plan Given by Expert." Hill completely supported the Mormon Flat plan. He, too, argued the soundness of the project's finances for the following reasons: the available connected electrical load greatly exceeded the combined capacity of all Association plants including the planned increase at Roosevelt. The Association needed to strengthen its electrical output and hence increase its electrical rates by developing a dependable production load, one that did not vary with the irrigation demand. Beyond the Association's need for power for drainage and groundwater pumping, Hill also recognized the existence of several large electrical users in the Valley which desired a firm power supply. For an investment of less than two million dollars, Hill concluded, the Association could irrigate more land, store

²"The Mormon Flat Development Plan and Its Possibilities," The Associated Arizona Producer 1 (December 1, 1922): 1-2.

³"Salt River Valley Farmers Have Store of Gold in Lake," The Associated Arizona Producer 1 (December 15, 1922): 1-2.

more water, better control the Salt River, and increase its gross revenues by \$400,000 per year.⁴

The Association asked its shareholders to vote on several proposals at the January 4 special election.

1. Should the Mormon Flat Development Number 1 as presented to the Association Board of Governors on November 15, 1922 be ratified?
2. Should \$1.8 million in bonds be issued to finance the construction?
3. Should the Board be given authorization to levy assessments against the shareholders' acreage to assure payment of the interest and principal of the bonds?
4. Should the Association's articles of incorporation be changed to reflect the additional indebtedness and to extend the life of the corporation an additional twenty five years?⁵

The campaign to sell the Mormon Flat development proved effective. The expansion program passed, 98,838 votes were cast in favor and 7,065 votes opposed. Reid and Cragin succeeded again. As The Producer bragged earlier, the Association was now ready to "make the largest and most remunerative power project in the southwest an accomplished fact."⁶

⁴"Financial Aspects of Salt River Plan Given By Expert," The Associated Arizona Producer 1 (January 1, 1923): 1-2.

⁵"Salt River Valley Water Users' Association, Special Election, January 4, 1923, Official Ballot," Record Group 115, Records of the Bureau of Reclamation, General Administration and Project Records, 1919-1929, National Archives and Records Administration, Washington D.C. Copy available at the Salt River Project Research Archives. Salt River Valley Water Users' Association, History of the Salt River Project For This Period, October 1, 1922 to September 30, 1923. Phoenix: Salt River Project Research Archives, 13.

⁶"The Mormon Flat Development Plan and Its Possibilities," 1; "Farmers Start Operations On Mormon Flat Development," The Associated Arizona Producer 1 (January 15, 1923): 1.
(Footnote Continued)

Reid and Cragin were confident that the Association's shareholders would approve the Mormon Flat plan. On the same day the special election was held, they released the development's bond prospectus. It explained, among other points, the purpose of the bond issue, feasibility of construction, the local power market, and the development's anticipated earnings. The investment advertisement also provided recent annual crop reports, photographs, legal documents, and Hill's previous Producer article which concluded, "In no case could the Water Users' Association lose."

Between January and March 1923, copies of the bond prospectus were distributed nationally to financial institutions. On March 22 all bids were opened. The winning bidders were Citizen's National Bank of Los Angeles and Amadeo Giannini's Bank of Italy of San Francisco. The bid price was \$.94 of par value at six percent interest, payable in fifteen to twenty five years from date of issuance. The Board accepted the amount, although it had hoped for better, because these bonds were the first issued by the Association and carried the "burden" of income tax. Additionally, Reid and Cragin did not want to delay beginning at Mormon Flat because they had already begun work at Roosevelt and it was nearing completion. They could not afford to have their construction crews remain inactive while the bonds were out for bid. Cragin estimated it would cost the Association \$40,000 per month for delaying the construction of Mormon Flat.

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1928): 5. The Producer did not report on the voting for each proposal. Presumably the vote total reflects the compilation of all yes and no votes for all proposals. Acreage voting is the Association's standard voting procedure, as provided for in its Articles of Incorporation and affirmed recently by the U.S. Supreme Court in its 1981 decision in James v. Ball.

⁷"Salt River Valley Water Users' Association (Roosevelt Dam Project), 6% Gold Bonds," January 4, 1923. Box 9300, Salt River Project Research Archives.

⁸History of the Salt River Project For This Period, October 1, 1922 to September 30, 1923, 11-13, 107. "Bonds Are Sold," The Associated Arizona Producer 1 (April 1, 1923): 9. "Mormon Flat Bonds - Transcript of Proceedings, 1923," RF1-#18; "Mormon Flat Bonds - Trust Indenture, Citizens Trust and Savings Bank, \$1,800,000, 6% Gold Bonds, 1923" RF1-#18; "Mormon Flat Bonds - Arizona Corporation

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Although the bonds were approved, interim certificates were sent to the banks because the legality of the bond issuance needed to be clarified. The Mormon Flat bonds were considered to be the first ever issued by an organization holding an outstanding debt to the federal government. Selling the securities presented two legal questions. What restraints, if any, did the federal government's prior lien hold on the project? What conflicts existed between the bond issuance and Association's articles of incorporation and the state corporation laws? These questions were answered in two friendly law suits decided by the Arizona State Supreme Court. The decisions, rendered by September 1923, were decided in favor of the Association in that they did not impede the organization from forwarding its financing plans.

Before the litigation and the outcome of the bond election were settled, Reid and Cragin began the Association's hydroelectric expansion program in December 1922 with work at Roosevelt. The Roosevelt construction was to develop an additional 10,000 horsepower at the power plant, making the plant's total output approximately 25,000 horsepower. This was accomplished by constructing nineteen Taintor gates, ten in the south spillway and nine in the north spillway. The new, fifteen foot high gates, each measuring fifteen by twenty one feet, gave the reservoir an additional 270,000 acre feet of capacity or 1.637 million acre feet of total capacity. The additional height gave the power plant a higher head. With this, the Association constructed another

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Commission, 1923," RF1-#18; "Mormon Flat Bonds - Legal Opinions, 1923," RF1-#18; "Mormon Flat Bonds - Miscellaneous - Sec'y. of Interior Approval, Resolutions, Legislation, etc., 1923," RF1-#18, Corporate Secretary's Office, Salt River Project, Tempe, Arizona. Giannini's Bank of Italy eventually evolved into the Transamerica Corporation. The decision to accept the bid was made by a committee of Reid, Association Vice-President C. S. Stewart, and three prominent Phoenix businessmen: Dwight B. Heard, Charles Akers, and T. C. McReynolds. The last concrete poured for the spillway piers at Roosevelt was accomplished in early March 1923.

⁹History of the Salt River Project For This Period, October 1, 1922 to September 30, 1923, 11-12; "Mormon Flat Dam Work Starts," The Associated Arizona Producer 2 (August 1, 1923): 2. The two lawsuits were: Orme v. Salt River Valley Water Users' Association, 25 Ariz. 324; and Green and Griffin Real Estate and Investment Company v. Salt River Valley Water Users' Association, 25 Ariz. 354.

penstock from the main sluice gate chamber. The new penstock was fourteen feet in diameter and 180 feet in length and served a 7,500 kw generating unit. In addition, the Association moved the power plant's transformer equipment from the transformer house located downstream of the power plant to the top of the power plant. This was done to eliminate the interruptions in service due to the heavy spray falling upon the wires crossing the south spillway at times when the reservoir was overflowing. The work at Roosevelt cost \$563,000. ¹⁰

While work was underway at Roosevelt, Cragin drafted an arch design for Mormon Flat. The plan for Mormon Flat Dam departed dramatically from the design the U.S. Reclamation Service used for Roosevelt. By the 1920s dam design technology had progressed significantly from the turn of the century. Consequently, the design used in constructing Roosevelt Dam had become obsolete. Built as a gravity dam, Roosevelt's success, like all gravity dams, relied on one simple principal: the measure of the structure's height and corresponding mass. Gravity dams work because the dam's height and thickness ratio, generally three to two, translates to a sufficient mass which resists water pressure by the force of gravity pulling the structure's weight down. Explained another way, the friction created between the dam base and foundation is sufficient to resist the calculated water load. ¹¹

¹⁰For more complete details on the Roosevelt Dam modifications, see History of the Salt River Project For this Period, October 1, 1922 to September 30, 1923, 14, 107-111, and photographs on pages 112-118; Salt River Valley Water Users' Association, History of the Salt River Project for This Period, October 1, 1923 to September 30, 1924, Chapter II, "Engineering," 1-3 and following photographs; and T. A. Hayden, "Salt River Project, Arizona, Irrigation and Hydroelectric Development by Salt River Valley Water Users' Association - Six Major Dams," Western Construction News 5 (June 25, 1930): 298-300. A six hundred horsepower unit was also added at Roosevelt to provide power to the plant.

¹¹For a clear description, with an illustration, of how a gravity dam resists water load, see Donald C. Jackson, "John S. Eastwood and the Mountain Dell Dam," The Journal of the Society For Industrial Archaeology 5 (1979): 37-38. Roosevelt Dam is arched but it operates as a gravity dam. Arching was added to give the structure an additional safety factor. For a good discussion on dam development see Donald
(Footnote Continued)

The extensive amount of material needed in constructing a gravity designed dam meant higher costs. To remedy the ever-increasing material, labor, and freighting costs in constructing gravity dams, engineering technology advanced the use of the arch design. The material's strength, and its placement in the form of an arch, not material mass, determines an arch dam's success. Curved upstream in plan, the arch dam uses the compressive strength of the structure's construction material, usually concrete, to deflect or transmit water load by arch action or thrust to the dam's abutment walls and foundation. The cantilever load carried by the dam face is resisted by the compression strength of the construction material. Unlike the gravity design, the arch dam's use of material strength, therefore, gives it structural merit. It did not rely on material weight or volume. This meant that the arch design resulted in a more economical and efficient use of material. The reduction in construction material made it appreciably less expensive to construct. ¹²

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C. Jackson, "A History of Water in the American West: John S. Eastwood and "The Ultimate Dam" (1908-1924)" (Ph.D. dissertation, University of Pennsylvania, 1986), 53-150; and Edward Wegmann, The Design and Construction of Dams (New York: John Wiley and Sons, 1927): 1-220. For a general history on dams, see Norman Smith, A History of Dams (Secaucus, New Jersey: The Citadel Press, 1972).

¹²For a thorough and excellent discussion of the evolution of the arch dams in the United States see section three, written by Jan A. Veltrop in Eric B. Kollgaard and Wallace L. Chadwick, eds., Development of Dam Engineering in the United States (New York: Pergamon Press, 1988): 219-554. The chapter also gives a valuable list of references at the conclusion of the section's text. See pages 314-317. For a good discussion on structural design versus the "aesthetic of mass," see David P. Billington, The Tower and the Bridge, The New Art of Structural Engineering (New York: Basic Books, 1983), and B. F. Jakobsen, "Volume Relation of Constant Angle Arch Dams and Gravity Dams," Engineering and Contracting 54 (December 8, 1920): 554. Beyond the structural advantages of the arch design, Jakobsen stated in his article that the design was significant because the "main aim of engineers should be to bring down the cost of engineering structures."

The use of the arch in dam construction dates to the Roman period. Over the centuries its application faded in Europe and in the Middle East. However, beginning in the late nineteenth century it developed growing popularity in the American West. The demand for low cost irrigation, flood control, and hydroelectric works, particularly in California, provided the impetus for the design's resurgence. The first American arch dam of note was Bear Valley Dam, completed by the Bear Valley Mutual Water Company in 1884 in the San Bernardino Mountains east of Los Angeles. The dam was 64 feet high but only 22 feet thick, a height to width ratio of nearly three to one. The design was considered so radical that it was referred to by James Dix Schuyler, a noted hydrologic engineer of the period, as the "eighth wonder of the world."¹³

After the success of Bear Valley Dam, the construction of other, larger, and more bold arch dams quickly followed. Perhaps the most daring of all arch dams to follow Bear Valley was the Upper Otay Dam which was completed in 1901. Built on the north branch of the Otay River outside the City of San Diego, the dam was 89 feet in height with a base thickness of only 14 feet. At the time of its completion Schuyler termed it the "slenderest dam in California or any other part of the globe."¹⁴ Because of the contributions Bear Valley, the Upper Otay, and others made to dam design

¹³For a review of Roman and Middle Eastern dams, see Smith, A History of Dams, 25-74. See also, Wegmann, The Design and Construction of Dams, 54-127. U.S. Department of the Interior, Geological Survey, "Reservoirs for Irrigation," Eighteenth Annual Report of the United States Geological Survey, 1896-1897, Part IV Hydrography. (Washington D.C.: Government Printing Office, 1897); Kollgaard and Chadwick, Development of Dam Engineering in the United States, 225-235. See pages 234-235 for the common characteristics of early arch dams. The original Bear Valley Dam, constructed of masonry block, was replaced by a more conservative concrete, multiple arch design built in 1911. For more on the reconstructed Big Bear Valley Dam, see Jackson, "A History of Water in the American West," 315-327.

¹⁴James Dix Schuyler, Reservoirs for Irrigation, Water Power, and Domestic Water Supply, 1st ed., (New York: John Wiley and Sons, 1905), 342-343. For a list of landmark arch dams, their concrete volumes, major dimensions, and ratios, see Tables 3-1 and 3-2 in Kollgaard and Chadwick, Development of Dam Engineering in the United States, 228-230.

technology, by the 1920s arch dams had become the preferred design type for narrow "U" or "V" shaped canyons. By 1922, more than eighty single arch dams and twenty-two multiple arch dams had been constructed in California. ¹⁵

In drafting the Association's design of Mormon Flat Dam, Charles Cragin was well aware of California's use of the arch design. He was familiar with the design specifications and construction methods of many of these dams through his association with Schuyler and other engineers who were members of the American Society of Civil Engineers. Cragin also drew experience from his activities in the design review and construction supervision of Cave Creek Dam, completed north of Phoenix in March 1923. Constructed as a flood control dam, Cave Creek employed a radical multiple arch design which used a minimum amount of concrete. Cragin was also aware that by 1923 another design appeared even more attractive than standard cylindrical arch or the multiple arch type for Mormon Flat, one which used even less construction material than either the gravity or traditional arch design. ¹⁶

In 1913, the Danish-born Lars Jorgensen, working as a consulting engineer in San Francisco, promoted a variation to the arch design. He suggested that the upstream radius, held constant in arch dams, be varied at different elevations. This would produce two benefits. More "economy of material" would result, and there would be greater arch action near the base of the dam. ¹⁷

¹⁵For a thorough discussion on the multiple arch dam and John S. Eastwood's contribution to the development of it, see Jackson, "A History of Water in the American West."

¹⁶For more on Cave Creek, see Wegmann, The Design and Construction of Dams, 482-486. In Wegmann, Cave Creek is referred to as "one of the most remarkable and boldest structures of the multiple-arch type that has been built." Jackson, "A History of Water in the American West," 638-653. Concerning Cragin's experience with Cave Creek, see Introcaso, "The History of Water Storage Development on the Agua Fria River," 83-84, 89-90. The Association did not construct Cave Creek but it did review and approve the design and partially fund the dam's construction.

¹⁷Lars Jorgensen, "The Constant-Angle Arch Dam," Transactions of the American Society of Civil Engineers, 78 (1915): 685-721. Lars Rasmus Jorgensen, was born in Faaborg, Denmark in 1876. Previous to his work in San

(Footnote Continued)

Jorgensen argued that the greatest economy of material in constructing an arch between two abutments must theoretically subtend an angle of 133 degrees and 34 minutes, or more practically 120 degrees. Maintaining a constant or central angle of this size from abutment to abutment and from crest to foundation would produce the maximum economy of material volume in any horizontal slice of the design. To maintain this angle, Jorgensen stated that the radius should decrease from the crest to lower elevations "in the same proportion as the canyon becomes narrower." In the constant radius design this did not happen. The angle in the constant radius became smaller at lower elevations. This resulted in the lower elevations losing arch action, leaving them to carry hydrostatic pressure using cantilever or gravity action.¹⁸

Jorgensen demonstrated the advantages of his variable radius arch design by explaining that it was able to resist full load better because it maintained its arch deflection strength by not flaring out at the foundation as the constant radius design did. Jorgensen argued that the deflection of an arch when stressed is proportional to the square of the length of the upstream radius. Therefore, since the radius lessened appreciably from the crest to the foundation, say for instance by four times, the deflection at the foundation would be sixteen times less than at the crest. The variable radius would then be able to carry

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Francisco, Jorgensen was employed by General Electric, Edison Electric, the Abner Doble Water Wheel Company, California Gas and Electric Corporation, and the F. G. Baum Company. His work concerned designing steam turbines, hydraulic power stations, railway systems, and masonry dams. In 1919 he formed the Constant Angle Dam Company of San Francisco to forward his variable radius, constant angle arch design.

¹⁸Between the angle of 120 and 150 degrees the variation in material volume is small; outside these limits, Jorgensen noted, the volume amounts increase "rapidly." Lars R. Jorgensen, "The Constant-Angle Arch Dam," 685-692. See also Figures 1 and 2 at pages 689 and 690. Jorgensen's proof for economy of material volume begins at page 689. Kollgaard and Chadwick, The Development of Dam Engineering in the United States, 245-246. For a good illustration showing the differences between a constant radius arch dam and a variable radius dam, see Figures 15 and 16 in Julian Hinds', "Continuous Development of Dams Since 1850," Transactions of the American Society of Civil Engineers, CT (1953): 506-507.

"sixteen times as much load at the bottom as an ordinary arch having a constant up-stream radius." Jorgensen concluded that his modified design would result in a materials savings of thirty-three percent over a gravity design and at the "same time possess a factor of safety more than twice as great as that of the gravity dam." ¹⁹

Soon after Jorgensen introduced the constant angle, variable radius design, several dams were constructed and operated safely using the variable radius plan. Consequently, Jorgensen's cone shaped dam design appealed to Charles Cragin. The variable radius design was feasible for Mormon Flat because the dam site approximated an almost ideal narrow "V" shape. More significantly, because the design used a minimum amount of material, the Association knew that it could advance its hydroelectric expansion plan at minimum cost. This was important since the Association and its farmers were just recovering from the post-World War I economic downturn. Using the variable radius design, Cragin originally estimated that dam would cost \$1.079 million or well within the \$1.8 million bond issue. ²⁰

¹⁹Lars R. Jorgensen, "The Constant-Angle Arch Dam," 686, 692. Kollgaard and Chadwick used Bullard Bar Dam as an example to show the changing radius from crest to foundation. Designed and supervised by Jorgensen, the dam was completed in 1924 on the Yuba River in California. At its foundation the dam had a radius of 94 feet, at its crest, 170 above, the upstream radius was 240 feet. See Figure 3-12 in Kollgaard and Chadwick, The Development of Dam Engineering in the United States, 245, 250. A problem with the variable arch was that the changing radius caused the design to overhang downstream at the upper elevations. This was remedied by decreasing the width of the dam as it rose from foundation to crest.

²⁰Salmon Creek Dam, 168 feet high and completed in 1914 by the Alaska Gastineau Mining Company of Juneau, and Lake Spaulding Dam, 225 feet high and erected by the Pacific Gas and Electric Company were the first dams to use the Jorgensen design. Many others followed. See Kollgaard and Chadwick, The Development of Dam Engineering in the United States, 246-255; History of the Salt River Project for This Period, October 1, 1923 to September 30, 1924, Chapter Two, "Engineering," 2. Cragin's selection of the variable radius was consistent with his approval of the multiple arch design for Cave Creek. He wanted to control the Salt River Valley's water supply at the least cost. John S. Eastwood, the designer of Cave Creek, drafted a preliminary design for

(Footnote Continued)

Cragin designed Mormon Flat Dam to approximate Jorgensen's variable radius constant angle arch design. The radius of the upstream face varies from a minimum of 100 feet at the narrowest part of the canyon to one of 187 feet at the top. The dam was designed to have a structural height of 229 feet with a hydraulic height of 142 feet. The base thickness is twenty feet at the approximate center and twenty-nine feet at the north haunch. It varies also where the foundation elevations change and at the penstock penetrations. Dam width tapers to eight feet at the crest. The thickness is held relatively constant at certain elevations from abutment to abutment. The crest length is 380 feet and the base width ninety feet. The original southside spillway was closed using nine Taintor or radial gates, each twenty-three feet high and twenty-seven feet wide, and all motor operated. Three of the gates were located above the ogee spillway; the remaining six were in an excavated section. The spillway's total discharge capacity was 150,000 cubic feet per second. The river outlet works consisted of seven penstocks: two were eight feet in diameter, two, six feet, and three, 4.5 feet. Using the variable radius arch design, the plan called for the use of 42,980 cubic yards of concrete.²¹

Compression stress was computed using the cylinder formula. This analysis was premised on the assumption that each elevation of arch ring is part of a thin cylinder which is subject to uniform load. Using this theory the dam was designed for maximum allowable stress at any elevation of 350 pounds per square inch (psi).²²

(Footnote Continued)

Mormon Flat. The multiple arch design was not forwarded at Mormon Flat possibly because Cragin wanted to avoid a repeat of the objections which plagued the early development of Cave Creek.

²¹Larry K. Lambert, "Mormon Flat Dam - Salt River Project, Phoenix, Arizona, U.S.A.," paper prepared for the United States Committee on Large Dams, October 30, 1986; Kollgaard and Chadwick, The Development of Dam Engineering in the United States, 271; T. A. Hayden, "Salt River Project, Arizona," 300-301; and "Arch Dam of Thin Section Now in Service on Salt River," Engineering News-Record 96 (May 13, 1926): 778.

²²By today's standards, using sophisticated computer and finite element analysis, the cylinder theory is very simplistic. It did not account for tension stress, gravity loads, elastic shortening, temperature changes, and other
(Footnote Continued)

For the Association Cragin's selection of Jorgensen's variable radius, constant angle arch was a judicious decision. However, it raised one question. Did it infringe on patents Jorgensen had obtained for the design in 1911, 1914, 1917, and 1918? Jorgensen and Karl Brehme, his partner in the Constant Angle Arch Dam Company of San Francisco, thought it did. After Brehme, and possibly Jorgensen, visited the Association's office in the spring of 1923, Brehme wrote Cragin in a January 1924 informing him that the Association needed to recognize Jorgensen's patents because the Bureau of Reclamation had paid the Constant Angle Company a royalty for their use in designing a dam on the Klamath Reclamation Project in Oregon. Brehme concluded his letter to Cragin stating, "The important bearing of this recognition of our²³ patents by the Government must be at once apparent to you."

Despite Brehme's warning, Cragin and the Association proceeded to construct Mormon Flat. Under legal advice, Cragin denied the validity of Brehme's claim. Writing to Brehme in March 1923, Cragin stated, "we are advised by our attorneys that since the design adopted merely embodies the application of old principles already well known, any patent

(Footnote Continued)

factors. Despite its shortcomings, it was an advancement over the previous use of the curved beam theory. The designed stress for Mormon Flat promised a high degree of safety. Using today's design criteria, compression stress can be as high as 1,000 psi or more. Kollgaard and Chadwick, The Development of Dam Engineering in the United States, 227, 239-244, 271; Lambert, "Mormon Flat Dam - Salt River Project," 2; Hinds, "Continuous Development of Dams Since 1850," 504. A simple formula for finding the thickness of an arch slice is given by Jorgensen in his "Constant-Angle Arch Dam," page 688.

²³Karl Brehme to C. C. Cragin, January 10, 1924, and Charles Townsend, Attorney for Constant Angle Arch Dam Company to C. C. Cragin, March 27, 1923, letters contained in File, "Leg., 9 Litigation, Constant Angle Arch Dam Company, 1923," Box 219-38, Records Management, Salt River Project. In a letter from R. F. Walter, Bureau Chief Engineer to C. C. Cragin dated February 18, 1924, Walter admitted that the Bureau paid the Constant Angle Arch Company \$500 in connection with the Gerber Dam on the Klamath Project. Letter contained File, "Leg., 9 Litigation, Constant Angle Arch Dam Company, 1923."

based thereon would be held void and . . . therefore, the payment of any money . . . would not be justified." ²⁴

The legal contention between Brehme and Cragin continued through the construction of Mormon Flat as well as through the Association's subsequent design and construction of Horse Mesa Dam. The matter was not settled until May 1930 when the Association agreed to pay Constant Angle \$15,000. In 1928 Constant Angle brought suit against the Association for patent infringement filing a legal claim for \$100,000. Just prior to the trial date in 1930, Cragin agreed to settle the suit for \$15,000. Cragin was certain that the Association would win the suit having learned that Jorgensen's patents might be invalid and that there had been at least one European dam built using different radii. However, Cragin and the Association Board settled because, as Cragin prudently stated, "We are confident that we could win the case, but I am satisfied the . . . settlement is the best for us in that it would cost us at least that much to win the case and [there is] no telling what might happen." ²⁵

Preliminary approval for the Mormon Flat Dam by the Reclamation Service was required under the 1917 agreement which transferred operation and maintenance of the Salt River Project to the Association. Initial approval for the Association's hydroelectric expansion plan was obtained under the July 1922 debt refinancing agreement. Final permission for the development was granted on February 2, 1923 when Secretary of the Interior Albert Fall approved the January 4 special election, the subsequent action by the

²⁴C. C. Cragin to the Constant Angle Arch Dam Company, March 19, 1923, File, "Leg., 9 Litigation, Constant Angle Arch Dam Company, 1923."

²⁵C. C. Cragin to Gene B. Heywood, April 17, 1930; C. C. Cragin to Fred H. Tibbetts, March 17, 1928; Fred A. Noetzli to C. C. Cragin, February 20, 1930; and Fred A. Noetzli to C. C. Cragin, April 2, 1930, File, "Leg., 9, Constant Angle Arch Dam Company, (Jorgensen Case), 1930," Box 219-38, Records Management, Salt River Project. Cragin learned that the Ponte Alto Dam built in the nineteenth century in the Italian Alps used the same design as his constructions. James Eastwood's design of Shoshone Dam may have also preceded Jorgensen's claims. See, James Eastwood, "An Arch Dam Design for the Site of the Shoshone Dam, " Engineering News 63 (June 9, 1910): 678-680. Cragin also believed that his dam designs were covered under a patent that had expired earlier in the 1920s.

Board to issue bonds, and the plans for the actual construction activities.²⁶

While Cragin completed drafting plans for Mormon Flat, preliminary work was begun. By April 1923, a 1.5 mile access road was completed to the site from the Apache Trail, the road running from Phoenix to Roosevelt Dam. Another road was constructed to replace 3.5 miles of Apache Trail that would be inundated by the Mormon Flat reservoir. This work began in June 1924. Under an agreement with the state of Arizona, the Association constructed this new stretch of road and turned it over to the State Highway Department upon completion. This was consistent with a previous agreement which turned over the entire Trail to the state. The Association completed the high line road in September 1924 which included the construction of a two timber trestle bridges over two creeks feeding the Salt River.²⁷

At the time work on the access road was being completed, transmission and telephone lines reached the dam site. In the summer of 1923 a construction camp was erected on the south side of the river one-quarter mile downstream from the site. It consisted of offices, three bunk houses, a mess hall, engineers' and superintendents' houses, a reading room, recreation hall, ice plant, bath house, ambulance garage, and other associated structures. A domestic water supply was developed for the camp by pumping water from the river 370 feet to an overlooking hill. Preliminary

²⁶Albert B. Fall to the Salt River Valley Water Users' Association, February 2, 1923, Bureau of Reclamation, Record Group 115, General Administration and Project Records, 1919-1929, National Archives and Records Administration, Washington D.C.; C. C. Cragin to D. W. Davis, Commissioner of the Bureau of Reclamation, July 13, 1923, Bureau of Reclamation, Record Group 115, General Administration and Project Records, 1919-1929. Copy of both letters are available at the Salt River Project Research Archives.

²⁷History of the Salt River Project For This Period, October 1, 1923 to September 1, 1924, Chapter Two, "Engineering," 2, 7. The Apache Trail was improved by the State Highway Department which incorporated the road into its system in 1922. The state made general improvements to the Trail, considerably reducing travel time for supply trucks to the Mormon Flat site. See Agreement signed between the Association and the State Engineer dated December 21, 1923, in File, "Leg. 1-2, 1920-1924, Construction, Improvements, and Maintenance," Box 219-37, Records Management, Salt River Project.

excavation work began in late summer using an electrically operated Monighan dragline excavator, which began building the upstream coffer dam. Excavation of the spillway and penstocks also started and a gravel pit, approximately one-third mile upstream, was located and a road to it completed. Diamond drilling exploration of the bedrock foundation was the only work not conducted by the Association; this was contracted out. With this exception all work was conducted by an Association force of ²⁸175 men, all that could maneuver in the narrow box canyon.

Controlling the flow of the Salt River was handled primarily by closing the newly-completed gates at Roosevelt. However, a significant amount of seepage and runoff developed below Roosevelt. This necessitated the construction of a diversion structure. A wooden flume 350 feet long, thirty feet wide, and fifteen feet high was constructed on a rock bench on the south side of the canyon. The timber side was secured by horizontal ties grouted into the side of the abutment and by supplemental cables. The flume was made water-tight by filling the timber seams with concrete. It was designed to pass 7,500 cubic feet per second, sufficient to convey irrigation water and runoff downstream from Roosevelt. Water was diverted into the flume by means of a coffer dam built of excavated river sand and gravel obtained from the developing foundation pit. A coffer dam was also constructed on the downstream side of the dam site to prevent tailwater from receding back into the excavation area. Although both coffer dams were not completed until December 1, 1923, river water was first diverted on October 10, 1923. With the river ²⁹regulated, the foundation excavation work began.

²⁸"Mormon Flat Dam Work Starts," 2; History of the Salt River Project For This Period October 1, 1922 to September 30, 1923, 108-110; History of the Salt River Project For This Period October 1, 1923 to September 30, 1924, Chapter Two, "Engineering," 2, 7; C. C. Cragin, "Mormon Flat Dam, Salt River Project, Arizona," New Reclamation Era 21 (June 1930): 110; T. A. Hayden, "Salt River Project, Arizona," 301; C. C. Cragin to D. W. Davis, July 13, 1923, File 480.1, Salt River Project Research Archives.

²⁹For a good review of construction progress with photographs, see History of the Salt River Project For This Period, October 1, 1923 to September 30, 1924, Chapter Two, "Engineering," 1-14; Cragin, "Mormon Flat Dam, Salt River Project, Arizona," 110; T. A. Hayden, "Salt River Project, Arizona," 301-302.

The narrowness of the canyon, the significant depth to bedrock, and the presence of seepage and percolating water made the foundation excavation very difficult. The bedrock, described as a hard, dense, homogeneous rhyolite breccia, was exposed using the Monighan dragline and a P. & H. gasoline shovel. The excavation pit was kept dry by a battery of six Kimball pumps which were designed to be used later as part of the Association's drainage program. The eighteen-inch pumps were electrically operated and each was capable of delivering twelve cubic feet of water per second. Wood and steel pilings and heavy timbering were used to shore up the pit embankments. Spoil was removed by a small wooden stiff-leg derrick and small dump cars which were moved atop a narrow gauge track. Sand and gravel were loaded on the cars which were then spilled, forming the downstream coffer dam. The excavation work was continued through the fall and winter of 1923. It was finally completed in March 1924 after approximately fourteen³⁰ thousand cubic yards of material had been removed.

Aggregate material for concrete was obtained from the river bed by the Monighan dragline also used to develop the upstream coffer dam and expose the foundation pit. The excavated material was consistent in size and therefore a crusher was not needed. All aggregate was screened, washed, and trucked over a road that ran along the south side of the river. The material was deposited in storage bins at the upstream³¹ approach to the spillway directly above the mixing plant.

The concrete mixing plant was small. It consisted of a single one-yard Smith mixer which had a production capacity of two hundred yards of concrete per eight-hour shift. Cement was purchased from the Southwestern Portland Cement Company of El Paso, Texas. Deliveries were made from Mesa using seven five-ton trucks. Each truck could make two

³⁰History of the Salt River Project For This Period
October 1, 1923 to September 30, 1924, Chapter Two,
"Engineering," 4-5; T. A. Hayden, "Salt River Project,
Arizona," 301-302; The Associated Arizona Producer 2 (March
1, 1924): 6; C. C. Cragin, "Mormon Flat Dam, Salt River
Project, Arizona," 111.

³¹T. A. Hayden, "Salt River Project, Arizona," 302; C.
C. Cragin, "Mormon Flat Dam, Salt River Project, Arizona,"
110; History of the Salt River Project For This Period
October 1, 1923 to September 30, 1924, Chapter Two,
"Engineering," 6-7. Another duplicate concrete mixer was
held in reserve but was not used.

round trips per day if necessary. Up to 25,000 sacks of cement were stored in a corrugated metal storehouse built above the mixing plant. Aggregate was moved by gravity from the storage bins above the mixing plant. Cement was delivered using chain blocks suspended from movable trolleys.³²

Concrete placement was accomplished using a 240 foot high Insley steel tower with sixteen-inch steel chutes. The tower was erected between February and May 1924. It was positioned near the mixer and could reach any section of the work. Concrete mixed at the plant was discharged down a chute that ran from the mixing plant to the base of the tower. Material was then lifted up the tower and distributed by the tower's chutes supported by sky lines. In addition to the placement tower, another smaller, steel guy derrick was erected at the south side of the canyon on the downstream side. This 105-foot derrick was built to supply forms and other materials during construction. It was served by another inclined track which ran from the cement mill.³³

Concrete was first poured on March 11, 1924. The construction plan was to build the dam in four separate arch ring sections with keyed faces. This permitted incorporating three evenly spaced contraction joints. Using this method the Association avoided the possibility of vertical cracks developing as the structure cured. Keying the sections provided a better bond when the openings were closed. By June 8 sufficient progress was made so that the river could be diverted through a pair of ten-foot openings left at the north end of the structure. A bulkhead was then installed to close the diversion intake and the flume was

³²History of the Salt River Project For This Period, October 1, 1923 to September 30, 1924, Chapter 2, "Engineering," 5-6; T. A. Hayden, "Salt River Project, Arizona," 302; The Associated Arizona Producer 3 (March 15, 1924); 5-6. See also photographs at page one of issue. Memorandum to Senior Engineer R. F. Blanks, U. S. Reclamation Service, May 12, 1944, by E. W. Ryland, 10. Copy of memorandum available at the Salt River Project Research Archives. The cement storage shed was completed in January 1924.

³³C. C. Cragin, "Mormon Flat Dam, Salt River Project, Arizona," 111; History of the Salt River Project For This Period, October 1, 1923 to September 31, 1924, Chapter Two, "Engineering," 6; T. A. Hayden, "Salt River Project, Arizona," 302.

removed to allow for concrete placement at the south end. By September 30, over fifty percent of the structure's total mass had been placed. ³⁴

Work continued through the remainder of 1924 and into 1925. Beyond pouring the dam face elevations, progress was made on the river outlet works and spillway. The six-foot penstocks were equipped with sliding gates on the upstream side. One of these gates was also given a control valve on the downstream end. These penstocks were reserved for possible future power installation. One of the 4.5 foot penstock openings was regulated using a needle valve; the other two used steel bulkheads. The three five-foot penstocks were closed using needle valves salvaged from the north tunnel at Roosevelt Dam. The 259 foot³⁵-long spillway was finished with nine steel Taintor gates.

In February 1925 Mormon Flat dam had risen to a sufficient elevation that water began to collect behind it. Two months later, in April, the dam was completed. Architecturally Mormon Flat was consistent with the Association's principal design criteria of least cost. As Cragin explained,

The dam is strictly utilitarian in construction and finish, without elaborate architectural treatment. The coping [parapet] consists of a plain 5-foot wall, broken into panels by plain pilasters. The character of the concrete was such as to leave a smooth surface against the forms, free from pockets, and the dam as a whole looks well finished and in keeping with the

³⁴Large concrete sections shrink when they cure. If constructed as one monolithic structure, Mormon Flat might possibly develop vertical cracks as it cured. To avoid the possibility of cracks the dam was constructed in sections. The only event which disturbed construction progress occurred in December 1923 before actual construction began. A flood left the site seventeen feet under water. Damage was slight, costing approximately \$2,000. "President Reid's Report," The Associated Arizona Producer 2 (March 1, 1924): 6. C. C. Cragin, "Mormon Flat Dam, Salt River Project, Arizona," 111-112; "Pouring Concrete Starts at Mormon Flat Dam --- Progress at Roosevelt," The Associated Arizona Producer 4 (March 15, 1924): 5-6.

³⁵C. C. Cragin, "Mormon Flat Dam, Salt River Project, Arizona," 111.

setting. 36

Mormon Flat Dam was constructed with efficiency and economy. The Association work force consisted of a maximum of only 225 men who generally worked three eight-hour shifts per day through the construction period. From first pour, work was completed in only thirteen months. The construction effort was also performed using a minimal amount of equipment. An electric and gasoline shovel, a concrete mixer, two towers, three hoists, two derricks, an air compressor, six pumps, and mechanically equipped carpenter and blacksmith shops were all the major equipment needed. Even scheduling construction activities was coordinated to use all equipment continuously. The construction plant layout was mechanized as far as possible so that all construction members could be moved and lifted with ease. The care taken in managing the construction effort was reflected in the dam's price. Cragin and the Association completed the work at a cost of \$1.23 million, only slightly more than the \$1.079 million originally estimated.³⁷

Soon after the dam was completed, the Association entered into an agreement with Central Arizona Light and Power Company (CALAPCO) to add a hydroelectric power plant. By leaving three penstock openings through the dam's face, the Association had acknowledged that it would some day add a hydroelectric unit, but did not plan the addition until a considerably later date. However, CALAPCO needed to expand its production supply and decided to take advantage of the developing energy stored behind the new dam. On June 29, 1925 the Association and CALAPCO entered into an agreement; CALAPCO would advance the Association \$410,000 for the construction of a single, 7,000 kw hydroelectric unit at Mormon Flat. In return for providing the up-front funding, CALAPCO would receive all of the plant's output.³⁸

³⁶Ibid., 112.

³⁷"Pouring Concrete Starts At Mormon Flat Dam --- Progress at Roosevelt," 5. For a list of equipment used in the construction of Mormon Flat, a line item cost analysis of the construction, critical dates in the construction of the dam, the structure's measurements, and additional photographs, see History of the Salt River Project For This Period, October 1, 1924, to September 30, 1925, Chapter Two, "Engineering," 3-24.

³⁸"Agreement Between Salt River Valley Water Users' Association and Central Arizona Light and Power Company,"
(Footnote Continued)

The agreement between the Association and CALAPCO was made possible by special legislation which was passed years before Mormon Flat was completed. Before Reid and Cragin took their hydroelectric expansion plan to the Association Board in the fall of 1922, they knew that to obtain the Board's, and the Secretary of the Interior's approval they needed to modify the 1906 Town Sites Act which limited power contracts under reclamation projects to a period of ten years. This act had served the Salt River Project's initial power plans well. Contracts with Inspiration and Miami copper companies enabled the Association to construct the Roosevelt to Miami transmission line; the Chandler Power Plant, the Valley's fourth, low-head hydroelectric plant built in 1918; and the Marinette substation. Under these agreements, the copper companies advanced construction funding. The 1906 legislation's ten-year limitation was adequate because the cost for these early construction projects were comparatively modest. The transmission line, at \$200,000, was the most expensive. Reid and Cragin realized, however, that the hydroelectric program would need longer contractual periods to secure adequate revenues to repay expansion costs. Cragin estimated the cost of developing the system, expanding Roosevelt and building Mormon Flat and Horse Mesa, at \$173 per kilowatt hour of production or over ten times the cost of the Association's previous hydroelectric expansion program. Recovering expansion costs, paying interest, accounting for depreciation and operating costs, and calculating a reasonable addition to income would require longer-term contracts.

With the assistance of Arizona Congressman Carl Hayden, the Association petitioned Congress to amend the Town Sites Act in the summer of 1922. In September 1922 Congress granted special legislative authorization enabling the Salt River Project to enter contractual agreements for a period of fifty years³⁹ with the Secretary of the Interior's approval.

Under the terms of the CALAPCO agreement the power company agreed to purchase hydroelectricity from the Association for a period of fifty years. For the first twenty-five years, the power company would buy a minimum of six million

(Footnote Continued)

June 24, 1925, File 480.1, Salt River Project Research Archives. The agreement has been amended and supplement several times since 1925.

³⁹Act of September 18, 1922, 42 Stat. 847. Pelz, Federal Reclamation and Related Laws Annotated, 302.

kilowatt hours per year. After that period, the annual minimum amount would be determined by mutual agreement or arbitration. Hydroelectricity would be sold to the power company at \$.008 cents per kilowatt hour. Reid and Cragin considered this a very favorable rate for the Association. The Producer reported that "similar power" had been sold recently in California at a rate of \$.0035 to \$.0045 cents per kilowatt hour. At the rate of \$.008 cents, the Association was ensured a minimum gross annual income of \$42,000 for the first twenty five years. Since the Association's repayment of the \$410,000 advancement, with six percent interest, equalled \$31,868 per year over a twenty-five year repayment period, minimum net income from the power company would still be no less than \$10,000 per year. Beyond the income from CALAPCO, Reid and Cragin believed that, based on the previous thirty-six year river flow records, the Mormon Flat plant could produce forty-three million kilowatt-hours annually with an annual gross income of \$344,000. Having the power company fund the construction, buy enough developed power to more than offset the debt repayment, and leave enough kilowatt-hours to produce \$312,000 in additional income, less operation and maintenance costs, was, Reid and Cragin believed, an exceptional opportunity. ⁴⁰

The Association began the power plant construction in July 1925. Initial work consisted of reconstructing some camp facilities and redeveloping the domestic water supply. Work on the power plant began with clearing a roadway to the site on the south side of the canyon. By fall, the excavation and construction of the draft tubes were completed. Through the winter and spring of 1926, the two eight-foot penstocks were joined into a single feeder penstock, the power house was erected, and all electrical equipment was delivered and installed. The plant was fitted with a single Westinghouse generator, with a rated installed capacity of 10,000 kw, and with a Westinghouse alternator, transformers, and switching equipment. The 10,000 horsepower waterwheel was provided by S. Morgan Smith. The plant was designed to operate under a maximum head of 154 feet, but could produce eight thousand horsepower when the reservoir contained only 30,000 acre feet, or was little more than half full. The Association

⁴⁰"Agreement Between Salt River Valley Water Users' Association and Central Arizona Light and Power Company," see Articles 5, 15, and 28. "President Reid's Report to Water Users' Association Tells About New Contract For Power Plant at Mormon Flat Dam, Water Supply Situation and Construction Progress," The Associated Arizona Producer 5 (August 15, 1925): 4-5.

also improved the temporary transmission system into Mormon Flat with new 110 kilovolt steel towers. The plant was finished in May 1926 at a cost, including changes to the power delivery system, of \$472,000.⁴¹

While the Association was constructing Mormon Flat Dam it prepared to further Cragin's expansion plan by initiating construction of the Mormon Flat Power Dam or Horse Mesa Dam. This it did in the spring of 1924. Horse Mesa Dam was located between Mormon Flat and Roosevelt dams and was planned to produce 33,000 kw of electricity. Work on Horse Mesa began in the summer of 1924 and was completed three years later in the summer of 1927.⁴²

⁴¹The Association did not need the approval of the Secretary of the Interior to construct the power plant. It was considered "additional works" of the Association. R. F. Walter, Chief Engineer, Bureau of Reclamation, to the Salt River Valley Water Users' Association, February 15, 1928, File, "POW, 4-2-3, Mormon Flat Hydro Plant, 1925-1927," Secretary Files, Box 219-37, Salt River Project Research Archives. T. A. Hayden, "Salt River Project, Arizona," 302; History for the Salt River Project For The Period, October 1, 1925 to September 30, 1926, Chapter 2, "Engineering," 2, 5-8; "Mormon Flat Power Plant Completed Ahead of Schedule," The Associated Arizona Producer 5 (April 1, 1926): 3.

⁴²For an account on the construction of Horse Mesa Dam see, David M. Introcaso, "Horse Mesa Dam," National Park Service, Historic American Record Engineering Report No. ?, 1989.

Chapter Four: The Construction of Horse Mesa Dam

Once the construction of Mormon Flat Dam was well underway in the summer of 1924, Charles Cragin and the Salt River Valley Water Users' Association prepared to complete their 1922 hydroelectric expansion plan. Referred to as the Mormon Flat Power Dam in Cragin's 1922 report, Horse Mesa Dam was to be constructed between Mormon Flat and Roosevelt dams. It would be the focal point of the project's electrical development. Horse Mesa would generate 33,000 kw of electricity and it was estimated that it would provide enough annual income to pay for the expansion, repay the federal government for Roosevelt Dam, and operate the Salt River Project.

The continuation of Cragin's hydroelectric program was made possible through a power sale agreement with the Inspiration Consolidated Copper Company. The mining concern, the largest business entity in the state of Arizona at the time, wanted to expand its mining operations in Miami by adding a \$6 million leaching plant. To operate the new plant, Inspiration needed additional electrical power. In June 1924 the copper company contracted with the Association to purchase all the¹ hydroelectricity generated from the planned Horse Mesa Dam.

Inspiration and the Association signed the agreement on June 14, 1924. Under its terms, Inspiration would buy all the power generated from the Horse Mesa Dam hydroelectric plant. It agreed to purchase potentially all the Association's hydroelectric power "which the Association may desire to furnish, from any source, up to the needs or requirements of the Company." The price for Horse Mesa power or any other Association plant was set at \$.0065 cents per kilowatt hour. Inspiration agreed to buy a minimum monthly amount of 7.25 million kilowatt hours. At \$.0065 per kilowatt hour, this equalled an annual payment of \$565,500. Inspiration further agreed to make this payment

¹P. G. Spilsbury, "Six Thousand Farmers Meet Twelve Thousand Business Men," The Associated Arizona Producer 3 (August 1, 1924): 1, 13; "Water Users-Inspiration Co-operation Makes Big Improvements Possible," The Associated Arizona Producer 3 (October 15, 1924): 3, 8. Inspiration Copper contracted with the Association for additional power based upon the recommendations made by consulting engineer Louis C. Hill. See Louis C. Hill, Quinton, Code and Hill, "Report, Inspiration Consolidated Copper Co.," June 27, 1922, 1-24. Copy of report is available at the Salt River Project Research Archives.

even if their power requirements were less than 7.25 million kilowatt hours, ² and whether or not power was made available to that extent.

The term of the agreement was for twenty-five years. After the first fifteen years, however, Inspiration had the right to reduce its minimum take by giving the Association at least twelve months' notice. Implementing the contractual terms was contingent upon the approval of the Association members to construct Horse Mesa and approve the necessary indebtedness to perform the work. Inspiration also required that the Association build the dam at least 262 feet above stream bed to ensure a sufficient head and kilowatt production, and that the work be completed in thirty-six months from the date of the contract. It also demanded that the Association construct two new transmission lines to the copper company's Miami facilities, each with sufficient capacity to ³ deliver all the power covered by the agreement.

After Reid and Cragin signed the Inspiration agreement they recommended that the Association Board approve the Horse Mesa plan. Cragin advised the Board to endorse the construction of Horse Mesa Dam and power plant and to change its present transmission system and erect a 110,000 volt loop tying in Roosevelt, Horse Mesa, and Mormon Flat dams with Goldfield, Superior, and Miami. Cragin estimated the cost of the expansion program at \$4.4 million. The probable income from the Inspiration agreement, Cragin thought, would far surpass the Association's minimum annual payment for debt service. Based on stream flow records beginning in 1903, Cragin computed that the total annual revenue from Horse Mesa would equal \$1 million dollars or nearly twice Inspiration's minimum payment. This amount, added to the balance of the Association's income accounts, would be sufficient to pay all the charges on interest and bond

²"Agreement Between the Salt River Valley Water Users' Association and the Inspiration Consolidated Copper Company," June 14, 1924. Copy available at the Salt River Project Secretary's Office. This type of contract is referred to as a "take and/or pay" agreement. The agreement was supplemented and modified in November 1924 and thereafter. A copy of the agreement was printed in the July 15, 1924 issue of The Associated Arizona Producer at pages 8 through 10.

³"Agreement Between the Salt River Valley Water Users' Association and the Inspiration Consolidated Copper Company," Articles 1, 3, 5, 11, and 27.

redemption for the Horse Mesa development, operate and maintain the Association's entire power and irrigation system, pay the federal government's construction charges for Roosevelt, and leave enough surplus to make improvements on the Project without any per acre assessments.

The Board approved the Horse Mesa construction unanimously. Again, needing Association shareholder approval to authorize the development, Cragin and Reid explained the further development of the Association's hydroelectric expansion plan through the pages of The Associated Arizona Producer and at nine public meetings held throughout the Salt River Valley between June 30 and July 25, 1924. Cragin was confident when he told the Association farmers, "The risk every farmer takes every year that he plants a crop . . . is a greater risk than the entire risk he will take with the Horse Mesa Development" "There is no possible chance to be taken in connection with the Horse-Mesa Project," Cragin asserted, because Inspiration Copper "is the largest power market in Arizona." Even without Inspiration, Cragin added, "The market for power in the Southwest is far ahead of the power development, and we cannot possibly go wrong in developing all the power we can."

Shareholder approval by special election of the Horse Mesa plan was scheduled for July 29. The Association shareholders were asked to vote on a somewhat complex list of eight propositions. Propositions one, two, five, seven, and eight were fairly direct. Did they support Cragin's Horse Mesa plan as presented to the Board? Did the shareholders agree to extend the Association's corporate

⁴The complete record of the Horse Mesa approval is contained in "Transcript of Record, Salt River Valley Water Users' Association, Relating to Construction of Horse-Mesa Development No. 1 and Issuance of \$4,743,000.00 - 6% Gold Bonds." Copy available at the Secretary's Office, Salt River Project. See also Cragin's letter to the Board dated June 20, 1924 contained therein.

⁵"Only \$2,500,000.00 in Bonds Necessary to Build \$4,400,000.00 Horse Mesa Project," The Associated Arizona Producer 3 (July 1, 1924): 2; "Horse Mesa Meetings," The Associated Arizona Producer 3 (July 1, 1924): 5; "Horse Mesa Election," The Associated Arizona Producer 3 (July 15, 1924) 3; "Horse-Mesa Election," The Associated Arizona Producer 3 (July 15, 1924): 2; "Successful Horse Mesa Meetings in Valley," The Associated Arizona Producer 3 (July 15, 1924): 5.

indebtedness? Did they approve \$2.5 million issue of construction bonds at six percent interest payable over fifteen years? Did they agree to the contract with Inspiration Copper? Were they willing to authorize levying assessments to assure the payment of⁶ the interest and principal on the \$2.5 million debt.

Propositions three, four and six were somewhat more complicated. The Association was issuing only \$2.5 million in construction bonds. The remainder of the \$4.743 million, or \$2.243 million, was raised through the Roosevelt Agricultural Improvement District Number One and the Agricultural Improvement District Number Two.⁷ District Number Two lands, 22,500 acres previously irrigated by the Tempe Irrigating Canal Company, were being admitted into the Association on the condition that they be used as collateral to issue \$1.578 million in bonds. The proceeds of these bonds were to be used to finance the construction of Horse Mesa. Similarly, the Roosevelt Agricultural Improvement District Number One, approximately 9,500 acres of dry lands scattered throughout the Project, would be permitted to obtain Association water on the condition that it issue \$665,000 in bonds to help fund the Horse Mesa plan. Repayment of both District One and Two bonds would be made from the sale of hydroelectric power from Horse Mesa Dam. The Association sought bonding from these districts because their bonds were tax free and would bring a higher bid price. The Association shareholders were thus asked to approve the issuance of these bonds in propositions three and four and obligate the Association to guarantee payment of these bonds under proposition six.

⁶"Salt River Valley Water Users' Association, Special Election July 29, 1924, Official Ballot," contained in "Transcript of Record, Salt River Water Users' Association Relating to Construction of Horse-Mesa Development No. 1 . . ."

⁷These agricultural improvement districts were formed under the authority of Title 45, Chapter 4, Arizona Revised Statutes (1922).

⁸Ibid. Lands under the Tempe Irrigating Canal Company did not sign into the Association after 1903 because the company had one of the oldest or senior water appropriation dates on the Salt River and therefore did not want to assume the construction debt for Roosevelt Dam. The Tempe lands joined the Association in 1924 because they needed the assistance of the Association's drainage program to lower

(Footnote Continued)

After the votes were tallied on July 30, 1924 a twenty to one margin approved the Horse Mesa development. Cragin and Reid were now ready to begin the last stage of their 1922 hydroexpansion plan. Before they could start, however, they faced another court challenge questioning the legality of the special election.

In Bethune v. the Salt River Valley Water Users' Association, the plaintiff, a shareholder, objected to the Association acquiring debt from the Agricultural Improvement districts and from its own proposed bond issuance. Bethune argued that the Association's Articles of Incorporation did not authorize it to construct dams and generating facilities, nor did it permit the Association to engage in speculative business enterprises thereby subjecting the landowners to financial risks. The Maricopa County Supreme Court and the Arizona State Superior Court denied Bethune's petition on July 19, ten days before the special election. The Superior Court affirmed the lower court's opinion ruling that the Association's "business expediency" whether "improvident or not," rests in the judgment of the Association, its officers and shareholders.

(Footnote Continued)

their high groundwater table. In order to join the Association, the Tempe lands were further required to pay \$800,000 in back assessments. The Tempe Canal lands signed into the Association on June 16, 1923. See "Contract, Tempe Irrigating Canal Company and the Salt River Valley Water Users' Association," June 16, 1923. Copy available at the Corporate Secretary Office, Salt River Project. About \$300,000 of the Districts' bonds would go to drainage and irrigation development. "Horse Mesa Election," 3; "Horse-Mesa Election," 2. The Roosevelt Agricultural Improvement District lands contracted with the Association on December 4, 1923. See "Contract, Roosevelt Agricultural Improvement District Number 1 and the Salt River Valley Water Users' Association," December 4, 1923. Copy available at the Corporate Secretary Office, Salt River Project.

⁹The vote showed 79,468 in favor of the development and 4,607 against. "Transcript of Record Salt River Valley Water Users' Association Relating to Construction of Horse-Mesa Development No. 1 . . . ;" "Horse Mesa Development Carried 20 to 1," The Associated Arizona Producer 3 (August 1, 1924): 2. Only 84,000 votes were cast in approving Horse Mesa's construction. This was less than half the eligible acreage votes. Shareholder turnout was traditionally low; however, it was used later by opponents of the hydroelectric expansion to criticize Reid and Cragin's efforts.

Consequently, if the Association proposes to expand its facilities then it is permitted to raise the necessary funds by "any legitimate means."¹⁰

While the Bethune complaint was being resolved, the Association circulated a prospectus detailing both the Improvement Districts' and the Association's bond issues to several hundred financial institutions throughout the United States. The prospectus contained information explaining the issue, a legal opinion supporting it, crop reports, the election ballot, and photographs of the Salt River Project, Valley farm lands, and urban Phoenix. On August 28, 1924 the Board opened all bids. The best of the seven bids received was made by the Anglo London Paris Company and its associates. The Board accepted Anglo's bid of 97.64 cents on the dollar.¹¹

Expeditious as always, Cragin began preliminary work at Horse Mesa a week before the construction bonds were issued. A six mile roadway to the dam from the Apache Trail, the road from Phoenix to Roosevelt, was started on August 23. The road camp had been established 1.5 miles in from the Apache Trail. Water for the camp was pumped up from the

¹⁰Quoted in, "Horse-Mesa Bond Issue Legalized by Supreme Court Decision," The Associated Arizona Producer 3 (August 1, 1924): 5; Bethune v. Salt River Valley Water Users' Association, 26 Ariz. 525; History of the Salt River Project For This Period October 1, 1923, to September 30, 1924, Chapter 13, "Litigation and Legal Work," 2.

¹¹"Salt River Valley Water Users' Association (Controlling), Roosevelt Dam and The Salt River Irrigation and Power Project, Offer Three Issues of 6% Gold Bonds (Non-Callable), Total Issue \$4,743,000.000," Copy available at the Secretary Office, Salt River Project. Anglo London Paris Company was San Francisco based. Its associates were: Stephens and Company and Freeman, Smith and Camp Company, both of San Francisco; Rutter and Company of New York; and Marshall Field, Glore, Ward and Company, and Stevenson, Perry, Stacy and Company, both of Chicago. "Meeting, Board of Governors, August 28, 1924 and August 29, 1924," contained within, "Transcript of Record, Salt River Valley Water Users' Association, Relating to Construction of Horse-Mesa Development No.1" "Wall Street Journal on Horse Mesa Bonds," The Associated Arizona Producer 3 (September 1, 1924): 14; "Horse-Mesa Bonds Sold at Highest Record Figure," The Associated Arizona Producer 3 (September 15, 1924): 3, 10; "The Bond Sale," The Associated Arizona Producer 3 (September 15, 1924): 5.

river under a static head of 1,200 feet. Electricity was supplied from the Roosevelt-to-Phoenix line and stepped down using temporary substations. Cragin was able to cut the road promptly because he had had it surveyed earlier in June.

The roadwork was difficult in the extreme, very time consuming, and expensive. This was because the area's topography from the Apache Trail to the dam site is exceptionally rugged and precipitous. Rock, loosened by explosives, was removed by an Osgood Steam Shovel and a P & H Gasoline Shovel. A Monighan Drag Line Excavator was brought upriver from the Mormon Flat construction after the roadwork was begun and used at the dam site. The job required the removal of over 350,000 cubic yards of solid rock. Work took until May 1925 to complete and cost \$408,000.¹²

Because the abutment walls at Horse Mesa rise almost vertically, about 1,500 feet, the dam site provided little room for a camp. Consequently facilities were dispersed for a mile downstream from the dam site on both sides of the river. Approximately twenty buildings, including an ice plant, machine, blacksmith, and carpenter shops, were located on the southside about a quarter-mile below the dam site. Until 1987, two gable-roofed, wood-framed bunk houses still remained at the site. Other wood-framed houses, including a school house, and tent structures were also erected along the southside access road. On the northside downstream from the dam site Apache workmen and their families constructed a separate camp on a narrow rock ledge. Water for the construction camp was pumped from the river to an elevated chlorinated tank. Because of the abrupt slope of the site's cliffs, preconstruction also required the early excavation of the dam's spillways and haunches. This was necessary to avoid possible injury to workmen from falling rock and debris.¹³

¹²C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," New Reclamation Era 21 (September 1930): 174; History of the Salt River Project For This Period October 1, 1923 to September 30, 1924, Chapter Two, "Engineering," 19-20; History of the Salt River Project For This Period October 1, 1924 to September 30, 1925, Chapter Two, "Engineering," 25-30 and photographs on pages 31-33. The road into Horse Mesa Dam presents some of the most spectacular scenery in the state of Arizona.

¹³A. E. Rogge and Cindy L. Myers, eds., "D-R-A-F-T, A
(Footnote Continued)

Cragin rushed Association workmen to prepare the dam site because the terms of the Inspiration contract left him only thirty-four months to complete the work. Cragin planned Horse Mesa using the same design method and allowable compressive stress that was used for Mormon Flat Dam, which was currently under construction downstream from Horse Mesa. He designed Horse Mesa as a three hundred foot high, constant angle arch dam, using the cylinder formula to compute compressive stresses. The Association's Chief Engineer selected the variable radius design for Horse Mesa for the same reasons he had chosen it for Mormon Flat: it was an appropriate design for the dam site and provided a cost savings in material. He submitted his design for Horse Mesa Dam to the Bureau of Reclamation for approval on August 16 expecting its quick endorsement.¹⁴ However, to his surprise, the Bureau rejected it.

Despite the previous success with Mormon Flat, on August 19, R. F. Walter, Chief Engineer of the Bureau, rejected the plan because he thought Horse Mesa was too high a dam to be analyzed using the simplistic cylinder formula. Walter wrote that, "if [the dam is] designed by this formula the actual stresses may exceed the calculated stresses by a large amount, and if this approximate method is to be used a much more conservative unit stress should be assumed, particularly for such a high dam as the one in question."¹⁵

(Footnote Continued)

Plan for Investigating Historic Dam Construction Camps in Central Arizona," (Phoenix: Dames and Moore, January 1987): 3-25. (Unpublished); History For The Salt River Project For This Period, October 1, 1924 to September 30, 1925, Chapter Two, "Engineering," 26; C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 174.

¹⁴Memorandum to Designing Engineer (Howell), August 16, 1924, Record Group 115, Office of Chief Engineer, General Correspondence, Files 262, Salt River, Box 1220, Eng. - Gen. 1/1916 - 1/1925. Copy of the memo is available at the Salt River Project Research Archives. The memorandum stated, "The above method of design [cylinder formula] cannot be condemned too strongly. This is especially true for this very high dam." Kollgaard and Chadwick, Development of Dam Engineering in the United States, 219-531, 314-317.

¹⁵Cragin also submitted the dam's power plant, transmission system, and the Inspiration contract with the dam design plans for approval. The hydroelectric plant and transmission lines were given preliminary approval and the contract was approved with "recommended" phrasing changes.

(Footnote Continued)

Walter suggested that Cragin instead use the trial load method to calculate stresses in Horse Mesa. As Walter explained, in this method,

the water load is distributed between the vertical cantilevers and the horizontal arch rings in such proportion as will result in equal deflections of the cantilevers and arch rings at all parts of the dam. The stresses in the cantilevers and arch elements are then calculated on the basis of their respective loading, proper allowance being made for rib shortening and temperature changes. The calculations for both the stresses and deflections are made in accordance with the elastic theory. The use of this method will probably result in a more economical design and a much better distribution of the concrete to withstand the loads. ¹⁶

Walter admitted that "while this [trial load] method is admittedly unsatisfactory, it is far more reliable than a design using the thin cylinder formula" for such a high dam. Walter sympathized with the Association because he understood the agreement it had with the copper company and the need to secure its construction bonds, but he added, "Our previous approval of a similar dam about 200 feet high . . . has evidently lead Mr. Cragin to expect approval of the design of Horse Mesa dam notwithstanding its height of 308 feet." ¹⁷

The Bureau's rejection of Horse Mesa could have been disastrous for Cragin and the Association: fortunately, it was not. Cragin's only problem was the potential adverse

(Footnote Continued)

R. F. Walter, Chief Engineer to Elwood Mead, Commissioner of Reclamation, August 19, 1924, Record Group 115, General Administrative and Project Records, 1919-1929, National Archives, Washington D. C. Copy of the letter is available at the Salt River Project Research Archives.

¹⁶R. F. Walter to Elwood Mead, August 19, 1924, 3.

¹⁷Walter thought the trial load method unsatisfactory because it too had shortcomings. Its assumptions also did not account for all factors. To assist Cragin, Walter suggested to Mead that he approve the design subject to revision or approve it with the understanding that the design of the dam be made satisfactory to the Bureau. R. F. Walter to Elwood Mead, August 19, 1924, 4.

effect the news would have on those preparing to bid on the bond issue. Considering the high bids the Association received, Cragin evidently kept the news quiet between August 19 and the bid opening on August 28. After the bidding, Cragin had nine months to redraft and recalculate his design for Horse Mesa because preconstruction, essentially the roadwork, would take until the following spring to complete. The difficulty of cutting the road, therefore, actually helped him because it kept the Association construction crews busy while giving him time to redraft the Horse Mesa design.

Walter did not leave Cragin to redesign Horse Mesa alone; he knew Cragin had no previous experience using the trial load method. Few people had. It had yet to be used to design a dam in the United States. Jogne Dam, completed in 1921 near Mont Salvens, Switzerland, was believed to be the only dam designed using the trial load analysis. In September 1924 Walter assigned one of his staff engineers to Phoenix to work with the Association in redrafting the Horse Mesa design. A. C. Jaquith was dispatched from the Bureau's Denver office to assist Cragin and his assistant, Francis O'Hara. Jaquith might have never used the trial load method, but he did have extensive experience designing arch dams for the Bureau. Previously, he had worked on several dams on the Klamath Project in California and Oregon, and on dams in the Umatilla Project in Oregon, the Riverton and Shoshone projects in Wyoming, the North Platte Project in Nebraska, the Boise and Minadoka projects in Idaho, and the Flathead Project in Montana. Jaquith arrived in the Valley in October 1924. ¹⁸

¹⁸G. T. Crowe to Elwood Mead, April 4, 1925, Record Group 115, General Administrative and Project Records, 1919-1929, National Archives, Washington D. C. Copy of letter available at the Salt River Project Research Archives. History of the Salt River Project For This Period October 1, 1924 to September 30, 1925, Chapter Two, "Engineering," 27; "Government Dam Expert Here to Help on Horse Mesa," The Associated Arizona Producer (October 15, 1924: 5. For information on Jogne Dam, also spelled LaJogne Dam, see Alfred Stucky, "Study of Arched Dams," Bulletin Technique de la Suisse Romande, 1922. Subsequent to the design of Horse Mesa's use of the trial load method, in 1926 the experimental Stevenson Creek Dam, a sixty-foot high simple arch dam, was constructed in California specifically to test for stresses. See Kollgaard and Chadwick, Development of Dam Engineering in the United States, 256-266.

During the next three months Jaquith and Cragin redesigned Horse Mesa based upon computations derived from the trial load method. Jaquith explained his work in an article he coauthored which was published posthumously in January 1928. The trial load method was necessary to determine the dimensions of Horse Mesa, he wrote, because the cylinder formula did not make allowance for "temperature changes, rib-shortening, or the effect of cantilever action." "The theory," he said, "is wrong and the resultant designs are uneconomical." "The lack of economy," he stated, "increases very rapidly as the size of the dam is increased."¹⁹

As Jaquith explained, the trial load method carries the dam's water load by using two systems of elements, one vertical as cantilevers, and the other horizontal as arches. "The two systems," he wrote, "have equal deflections at all points and carry proportional parts of the load." Assuming this, Jaquith concluded,

there is certainly some definite division of the load that will give equal deflections for both systems at all points. This division can be found approximately by applying a series of trial proportionate loads to each system. If enough trials be made, equal deflections for arch and cantilever elements at all points will finally be found for any assumed temperature

¹⁹Jaquith coauthored the article with a Bureau associate, C. H. Howell. Jaquith died in September 1927, soon after Horse Mesa was completed. C. H. Howell and A. C. Jaquith, "Analysis of Arch Dams by the Trial Load Method," Proceedings of the American Society of Civil Engineers 54 (January 1928): 61-95. For specifics on the design of Horse Mesa, see pages 74-76 and the Appendix, pages 78-91. The article was also published under the same title in the Transactions of the American Society of Civil Engineers 93 (1929): 1191-1316. This version also contains a lengthy discussion. See also "Design of Horse Mesa Dam, Maricopa County, Arizona," March 1925, 1-15, Record Group 115, General Administrative and Project Records, 1919-1929, National Archives, Washington D. C. Copy of the document is available at the Salt River Project Research Archives; Kollgaard and Chadwick, Development of Dam Engineering in the United States, 266-267; History of the Salt River Project For This Period October 1, 1924 to September 30, 1925, Chapter Two, "Engineering," 27-30; and H. M. Westergaard, "Arch Dam Analysis by Trial Loads Simplified," Engineering News-Record (January 22, 1931): 141-143.

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The maximum stress allowed in calculating the design was 650 pounds per square inch. The average compression in the arches was calculated at 286 pounds per square inch, and in the cantilevers at 222 pounds per square inch. The final design resulted in irregular arch ring shapes, much different from the earlier, simple, circular arcs. For instance, the arch ring at the lower part of the dam was thickest at the abutments, thinnest at the quarter points, and thickening again at the crown. This eliminated unsymmetrical loading of the arches and caused uniformly stressed concrete. After the many trial loads had been calculated, usually ten for each horizontal and vertical section to achieve the desired deflection, Jaquith and Cragin were left with a design that held material savings of approximately eighteen percent over the initial plan. ²¹

Jaquith's and Cragin's redesigned Horse Mesa Dam stood 305 feet high from bedrock to the top of the coping. The dam had a hydraulic height of 266 feet above stream bed. As a variable radius type, the upstream radius at the crest measured 251.4 feet, and eighty-two feet at the base. Thickness at the base varied from forty-three to fifty-seven feet. The dam was eight feet thick at the top. The maximum span of the arch was 450 feet. The upper 175 feet of the north end thrust against an ogee gravity overflow section, 140 feet long on the crest. Storage capacity was calculated at 245,000 acre feet with an additional 15,000 acre feet possible if the upper six feet of coping is used. The north and south spillways were closed by nine steel Taintor gates, six on the north side, and three on the south. All gates were motor operated and equal in dimension to those used at Mormon Flat. They measured twenty-three feet high by twenty-seven feet wide. Spillway discharge capacity was estimated at 150,000 cubic feet per second. The power plant outlets consisted of three penstocks, each eight feet in diameter located at the center of the dam. ²²

²⁰Howell and Jaquith, "Analysis of Arch Dams by the Trial Load Method," 62-63.

²¹Howell and Jaquith, "Analysis of Arch Dams by the Trial Load Method, 74-75; "Design of Horse Mesa Dam," 2; History of the Salt River Project For This Period October 1, 1924 to September 30, 1925, Chapter Two, "Engineering," 28.

²²C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 174; T. A. Hayden, "Salt River Project, Arizona," (Footnote Continued)

Cragin submitted the final design for Horse Mesa to the Bureau on April 3, 1925. Because the Bureau essentially redesigned the dam through Jaquith, it approved the plans ten days later, on April 13. Even though the Association received approval eight months late, Cragin's crews were still a year away from actual construction. The road work was still several weeks from completion. Association work forces needed to begin excavating the spillways and prepare the abutment contacts before men could work in the stream bed. They were also busy installing the permanent 110 KV line into the dam site, replacing the 45 KV wood pole line from Goldfield to Superior with a 110 KV steel pole line, and moving equipment to the dam from the road camp. Added to all this, the Association was just finishing Mormon Flat and was soon to undertake the construction of a hydroelectric plant there. ²³

Completing the above-ground excavation carried the Association through the remainder of 1925 and into the spring of 1926. This work was at least as difficult as building the access road. Nearly the entire length of both spillways had to be excavated out of the canyon walls. Over 500,000 cubic yards of solid and loose rock needed to be removed. By March 1, 1926 the job was finished. After over a year and a half, ²⁴ Cragin and his men were ready to begin work on the dam.

(Footnote Continued)

Part II, " Western Construction News 5 (July 10, 1930): 319-320; History of the Salt River Project For This Period October 1, 1924 to September 30, 1925, Chapter Two, "Engineering," 27-28.

²³G. T. Crowe to Elwood Mead, April 4, 1925; P. W. Dent, Acting Commissioner, Bureau of Reclamation to Hubert Work, Secretary of the Interior, April 13, 1925, Record Group 115, General Administrative and Project Records, 1919-1929, National Archives, Washington D. C. Copy of this letter is available at the Salt River Project Research Archives. The road to the camp site below the dam was passable by March but was not completely finished to the dam until May. C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 174; History of the Salt River Project For This Period October 1, 1924 to September 30, 1925, Chapter Two, "Engineering," 30.

²⁴From solid rock, the Association excavated 421,000 cubic yards and in loose material, 117,000 cubic yards. Work was taken to sufficient depth to eliminate the

(Footnote Continued)

Foundation excavation, a simple open cut, was accomplished using the P & H shovel and Osgood steam shovel which were made available after the road grading was completed. These pieces were converted into drag lines and used in conjunction with the Monighan shovel, which had been released from Mormon Flat. The bedrock geology, composed of the same rhyolite breccia found at Mormon Flat Dam and throughout the area, was inspected by representatives of Inspiration and Anaconda Copper companies, by the Bureau, by Cragin and O'Hara, and by P. J. Lynch who was in charge of construction. Excavation at the south haunch was carried to a horizontal depth of 125 feet due to the appearance of several large seams. Grouting holes were staggered over the entire base of the dam. These holes were drilled to a depth of thirty feet and grouted with one part cement and one part sand under thirty pounds of pressure. Grouting was carried into the bedrock from holes left in the concrete after the dam reached a height of fifty feet. Grout work was also done at the sides of the north and south haunch, and at the south spillway. Grout pressures of up to two hundred pounds per square inch were used for depths of fifty to two hundred feet.²⁵

The Salt River was controlled primarily by closing the gates at Roosevelt Dam. Downstream runoff below Roosevelt by-passed the construction area through a wooden flume measuring three hundred feet long, twenty feet wide, and ten feet deep. The flume was placed at the south end, or left side, of the foundation work. Water was channeled into the flume by a sand and gravel coffer dam. The 22,000 cubic yards of questionable foundation rock was used to create a spoil bank or downstream coffer dam to prevent tail water from receding into the foundation pit. Seepage water was removed from the foundation area by four Kimball pumps recently used for the same purpose at Mormon Flat.²⁶

(Footnote Continued)

appearance of any seams. C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 175.

²⁵For the specifics on the grouting program at Horse Mesa, see C. C. Cragin to D. C. Henny, Consulting Engineer, April 21, 1928, Historical File 480.2, Salt River Project Research Archives. See also C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 175.

²⁶C. C. Cragin to D. C. Henny, April 21, 1928; C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 175; "Construction Progress Salt River Project," The Associated Arizona Producer 3 (March 15, 1926): 5.

The method by which Cragin and his engineering staff obtained sand and gravel for concrete was unusual for this class of construction. Aggregate was obtained by dredging the river. Gravel bars in the stream bed from .75 miles to three miles upstream from the dam site were dug using a pair of three cubic yard electrically operated clamshell derricks. Buckets were mounted on forty by sixty foot barges built at the dam site. Excavated material was dumped onto three scows having a forty yard or six ton capacity. These were then towed to the dam site by two tugboats which the Association purchased in San Francisco and trucked to the site. At the dam site a third clamshell unloaded gravel from the flat bottomed boats and deposited it through a separator, called a grizzly, and then into a bin. From there aggregate was dumped into cars which then travelled 350 feet above the stream bed to another storage bin. The system was so automated that the unloading derrick rose along with the water level behind the dam. The dump cars operated automatically on a double track synchronized so that the empty car was counterbalanced to descend while the full car ascended. ²⁷

The mixing plant, along with the gravel, sand, and cement storage bins, was literally perched on a small bench against the southside cliff, fifty feet above the south spillway. A pair of one-yard mixers from Mormon Flat and the another held in reserve were used to mix the concrete. Aggregate was discharged automatically in measured quantities into the mixers where the correct amount of cement was added. Water was poured automatically through a device called an inundator.

Fresh concrete was then moved to the Insley tower which had been reconstructed on the south overhang after being disassembled at Mormon Flat. Built three hundred and forty feet high, and seven hundred feet above the stream bed, the tower hoisted concrete and then dumped it into twenty-inch

²⁷ Towards the end of construction the clamshells were obtaining aggregate from water up to one hundred feet deep. The tugboats were brought to Mesa by rail and then trucked to the dam site. Aggregate was separated into a three compartment bin. One bin contained sand, another gravel under three inches in diameter, and another with material three to six inches in diameter. C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 175; History of the Salt River Project For This Period October 1, 1925 to September 30, 1926, Chapter Two, "Engineering," 2-3; "Pouring Concrete in Progress at Horse Mesa Dam," The Associated Arizona Producer 4 (June 1, 1926): 2-3.

"down comer" chutes positioned to fill the construction forms. A total of one thousand feet of chute lines were used. The long steel tower members were suspended from sky lines and offset by a pair of seventy-five foot counter balances. The other Insley steel guy derrick used at Mormon Flat was also employed at Horse Mesa. It was positioned just above the south spillway and was used to move forms and rehandle material. Cement was delivered to the mixing plant by twenty-seven, five-ton Pierce-Arrow trucks which hauled cement and other material forty-four miles from Mesa. Cement sacks were unloaded at the storage shed through the use of an automated belt conveyor.

Concrete was first poured for Horse Mesa Dam on May 26, 1926. From that day, concrete was placed almost continuously. Six-inch diameter plums were added to the freshly poured concrete to guarantee that each pour completely filled the form. As in the construction of Mormon Flat, contraction joints were left in the work. Five evenly-spaced openings divided the dam into six separate sections. The faces of the adjacent edges were keyed and the hardened concrete was painted with asphalt before fresh concrete was poured against it. Filling the gaps was done a minimum of thirty days after pouring the original concrete. Concrete was used to grout the contraction joints at two hundred pounds of pressure.

From May through the remainder of 1926, the dam rose steadily. Although both concrete mixers could produce about a thousand cubic yards per day, actual progress averaged about half that. By July, the diversion flume was torn down because the dam had risen sufficiently to install the penstock openings. Water was then conveyed through the three penstocks. By December 1926 the dam had risen more than one hundred feet from the foundation. By the end of

²⁸The Insley tower was erected one hundred feet higher than it had been at Mormon Flat. C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 175; History of the Salt River Project For This Period October 1, 1925 to September 30, 1926, Chapter Two, "Engineering," 3; Kollgaard and Chadwick, Development of Dam Engineering in the United States, 7; "Pouring Concrete in Progress at Horse Mesa Dam," 3.

²⁹C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 175; "Pouring Concrete in Progress at Horse Mesa Dam," 3; History of the Salt River Project For This Period October 1, 1925 to September 30, 1926, Chapter Two, "Engineering," 3.

the year the Association had also completed all of the 110 KV transmission lines.³⁰

As work continued into the spring of 1927, it was necessary to raise the water level in the reservoir as quickly as construction would permit. The Association needed to bring the reservoir up to the spillway level to meet the coming summer irrigation demand. Water stored behind Mormon Flat Dam had been nearly exhausted the previous summer. Its reservoir had only thirteen thousand acre feet remaining. By July 1 Horse Mesa Dam reached its spillway crest elevation and water was released to Mormon Flat.³¹

There was another advantage in immediately filling the reservoir behind Horse Mesa - hydroelectric benefits. Cragin constructed the hydroelectric power plant at the same time he built the dam. The floor for the plant was poured in July 1926, two months after the first concrete laid for the dam foundation. In April 1927, while the dam face continued upward, the power plant building was finished and the first of its three 10,000 kw hydroelectric generating units was placed in operation. Initially, the unit operated under a marginal head of 119 feet. But because the Association filled the reservoir rapidly, all three turbines were running under a full head by the summer. The early completion of the power plant provided the Association two benefits. It satisfied Inspiration's thirty-six month contractual provision, and it allowed the Association to pay for the project's construction costs while the dam was still being built. Through the end of construction, the hydroelectric plant generated twenty-two million kilowatt hours for a net profit of approximately \$150,000.³²

³⁰ Ibid; "Construction Progress --- Horse Mesa Dam," The Associated Arizona Producer 4 (August 1, 1926): 5.

³¹ "The First Foot of Water Over The Spillway at Horse Mesa Dam July 1, 1927," The Associated Arizona Producer 4 (July 1, 1927): 1, 5.

³² History of the Salt River Project For the Period October 1, 1925 to September 30, 1926, Chapter Two, "Engineering," 3; History of the Salt River Project For the Period October 1, 1926 to September 30, 1927, Chapter Two, "Engineering," 2; "Horse Mesa Power Plant Starts Producing Income at Rate of \$2,000 a Day," The Associated Arizona Producer 4 (April 1, 1927): 3, 5; "Farmers Get Big Income From Horse Mesa Development," The Associated Arizona Producer 4 (May 1, 1927): 5; "Last Concrete Poured at Horse
(Footnote Continued)

On August 4, 1927 the last of the dam and power plant's 152,000 cubic yards of concrete was poured. All the forms were stripped by October 1. The only remaining work item for the project was the realignment of 7.5 miles of the Apache Trail, inundated by the reservoir formed behind Horse Mesa Dam. This work was completed by the State Highway Department under an April 29, 1922 contract with the Association. Under the agreement, the Highway Department agreed to take over maintenance of the road from the Association and integrate it into its state road system. 33

Horse Mesa cost \$5.319 million. This exceeded the \$4.743 million estimate by \$576,000. Considering the expense in accessing the site, performing the above-stream excavation, and employing seven hundred men at the site, Cragin did not believe the overrun excessive. In fact, he felt fortunate because costs could have been considerably higher. The redesign of the dam, he calculated, produced a material savings estimated at \$30,000. The Association saved \$200,000 by hauling equipment and material to the dam site itself. The availability of Association equipment and an experienced labor force also saved an appreciable amount. "The ability to synchronize construction work with ordinary project operations, and the savings effected in supervision and in the ability to change plans to meet conditions encountered," Cragin wrote, "combined to give the force account method of construction an advantage over contract work, the gross savings being conservatively estimated at \$500,000." 34

The completion of Horse Mesa Dam in the fall of 1927 did not signify an end to the Association's hydroelectric expansion program. More work remained. Before Cragin and the

(Footnote Continued)

Mesa Dam --- Power Income For Year Over \$1,500,000," The Associated Arizona Producer 4 (August 15, 1927): 5.

³³C. C. Cragin, "Horse Mesa Dam, Salt River Project, Arizona," 176; History of the Salt River Project For This Period October 1, 1926 To September 30, 1927, Chapter Two, "Engineering," 3.

³⁴History of the Salt River Project For This Period October 1, 1926 to September 30, 1927, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 6-8. The only unanticipated expense in the construction of Horse Mesa was repairing the damage from a fire in the camp. This was a nominal cost of \$381. For an itemized list of Horse Mesa Dam construction expenses see Chapter Two, "Engineering," 4-21.

Association rested they saw that additional hydroelectric output could be produced by taking advantage of the Salt River's drop between Mormon Flat and the Project's river diversion works at Granite Reef.

Chapter Five: Post-Construction: Additions to the Association's Hydroelectric Program and Modifications to Mormon Flat and Horse Mesa Dams

The completion of Mormon Flat and Horse Mesa dams in 1927 did not signify an end to the Association's hydroelectric expansion program. In Cragin's 1922 report he included the possibility of developing the Salt River below Mormon Flat Dam. In his study, Cragin stated that the "final step in developing the full head of the Salt River between Roosevelt and Granite Reef" would be to divert water off the Salt and convey it through a canal to the Verde River where it could be run for power. To do this, he suggested that a dam be built at Stewart's Ranch or Stewart Mountain, approximately ten miles below Mormon Flat. Salt River water could then be diverted into an eighteen mile canal running to the Verde River. Salt River water could generate power or be stored on the Verde behind another, yet unbuilt dam, when the irrigation demand was low and water was run for power only or when the Salt was running for irrigation and power production. Cragin did not clearly describe his plan for this stage of the development, providing no explanation why the Project should use Salt River water to generate hydroelectric power on the Verde River. Regardless, he realized that there was another two hundred feet of drop between Mormon Flat and Granite Reef that could be used to generate more hydroelectricity.¹

In 1922 Cragin had left the development of the Salt River below Mormon Flat to "some future time" when the value of power and the growth of the Valley required it. In 1928, circumstances demanded it. In Phoenix and surrounding area CALAPCO delivered twenty-four million kilowatt hours of electricity in 1923. In 1927, it delivered forty-one million kilowatt hours, sixteen million kilowatt hours of which were provided to it by the Association. By 1932, CALAPCO estimated that its load would more than double to eighty-four million kilowatt hours. CALAPCO's need for additional Association hydroelectric power was certain. Added to this, the Association was feeling the demand for increased domestic rural electrical service from its shareholders. It received over one thousand applications for electric service from its members in 1927. Also, the construction of a dam at Stewart Mountain offered the Association the ability to satisfy its irrigation demand more quickly since the regulating facility would be closer to Granite Reef Diversion Dam. For these reasons, Cragin

¹Cragin, "Report on Proposed Additional Hydro-Electric Power Development of the Salt River," 32-33.

and Reid proposed² in 1928 to construct a third power dam on the Salt River.

Cragin constructed Stewart Mountain Dam using the same fiscal formula he used to fund the construction of Mormon Flat and Horse Mesa dams: securing agreement with industry to buy a minimum of hydroelectric output. On February 8, 1928, the Association and CALAPCO entered into a fifty year agreement whereby CALAPCO would purchase seven thousand kilowatts of power generated from the proposed ten thousand kilowatt power plant at Stewart Mountain. At \$.008 cents per kilowatt hour, the Association could anticipate an³ annual revenue of \$520,000 from the CALAPCO agreement.

In May 1928 Association shareholders approved a bond issue for \$4.1 million for Stewart Mountain Dam's construction. Of this amount, \$2.3 million would be used to construct Stewart Mountain; \$1.2 million would be used to pay for the Valley electrical distribution system to service primarily Association rural shareholders; and \$600,000 would be used to repay a portion of the original Roosevelt Dam debt owed the federal government. The bonds were sold in June and construction began in October, immediately after money became available from the bond sale.⁴

²"The Stewart Mountain Development," The Associated Arizona Producer 6 (February 15, 1928): 1; "Details of Stewart Mountain Development," The Associated Arizona Producer 6 (February 15, 1928): 2, 11.

³The \$.008 rate was fixed for the first thirty years of the contract. After that period the rate became negotiable. The February 1928 CALAPCO contract was printed in full in "Stewart Mountain Contract," The Associated Arizona Producer 6 (February 15, 1928): 4-5, 8-9, 11-12; "Details of Stewart Mountain Development," 11; History For the Period October 1, 1927 to September 30, 1928, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 6. See also, John Quincy Jewett, "Economic Analysis of the Hydro-Electric Power System of the Salt River Irrigation Project in Arizona," (M.A. thesis, University of Colorado, 1929), 41-43.

⁴Bonds were approved by special election on May 8 after the first election held on March 20 failed to get the required three-fourths ratio needed for approval. There were two bids accepted for the issuance. The first bid was for \$.9686, but after litigation challenging the bonding delayed the award, the bidders withdrew their offer. The highest bid under the second set of proposals was for \$.93

(Footnote Continued)

Stewart Mountain Dam was also designed as a variable radius constant angle arch dam. The dimensions of the 212 foot high dam were computed using the trial load method. Storage capacity behind the dam was calculated at seventy thousand acre feet. The power plant was served by a 13.5 foot diameter penstock. The plant was fitted with a single, 17,500 horsepower generating unit. Three additional openings were provided: a pair of seven foot diameter penstocks, and another eight feet in diameter. The east side spillway was closed using nine Taintor gates the same size as those at Mormon Flat and Horse Mesa dams. The spillway had the same estimated discharge capacity of 150,000 cfs. Work on the dam and power plant was completed in March 1930 and power was made available that same month. The cost of the work exceeded the \$2.3 million estimate by \$190,000. The increase was due to 45,000 cubic yards of added concrete needed to completed the work due to the conditions found while excavating the site.

(Footnote Continued)

at 5.5 percent interest. This was accepted. History of the Salt River Project For This Period October 1, 1927 to September 30, 1928, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 8, and Chapter Two, "Engineering," 2-5. For information on the bond issuance, see "Stewart Mountain Development and Valley Electrification Now up to Vote of Farmers," The Associated Arizona Producer 7 (March 15, 1928): 3; "Do You Want Electricity in Your Home?" The Associated Arizona Producer 7 (March 15, 1928): 11; "The Other Side of the Stewart Mountain Question, What Opponents Advocate," The Associated Arizona Producer 7 (May 1, 1928): 1; "Facts About the Salt River Project Power System and Stewart Mountain Development," The Associated Arizona Producer 7 (May 1, 1928): 2, 5; "Stewart Mountain Development and Valley Electrification," The Associated Arizona Producer 7 (May 15, 1928): 1; "The Stewart Mountain Power Development," The Associated Arizona Producer 7 (September 15, 1928): 4; "Contract for Sale of Stewart Mountain Development Bonds," The Associated Arizona Producer 7 (September 15, 1928): 5.

⁵For construction information, see History of the Salt River Project For The Period October 1, 1927 to September 30, 1928, Chapter Two, "Engineering," 2-5; History of the Salt River Project For The Period October 1, 1928 to September 30, 1929, Chapter Two, "Engineering," 2-12 and drawings and photographs following; History of the Salt River Project For The Period October 1, 1929 to September 30, 1930, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 11-12, and Chapter Two, "Engineering," 2-6; T. A. Hayden, "Salt River Project,

(Footnote Continued)

While Stewart Mountain was under construction, the Association also completed its Valley electrification program. From November 1928 through September 1929, Association work forces erected seven hundred steel poles over a distance of four hundred miles and constructed eight substations. The completion of the electrification program enabled the Association to increase its rural service dramatically. While lines were strung, the Association nearly doubled the number of those shareholders receiving electrical power. In 1928-1929, 1,638 new customers were added to the 933 shareholders already receiving power. The electrification program was not inexpensive. The work's cost exceeded the projected estimate of \$1.2 million by nearly twenty percent, or \$261,000. This was due primarily to the unanticipated difficulty in meeting right-of-way requirements in constructing the substations.

The completion of the rural electrification project marked the end of the Association's hydroelectric expansion program. After eight years of planning and construction, the \$12.5 million development was complete. The added generating capacity at Roosevelt and the construction of hydroelectric plants at Mormon Flat, Horse Mesa, and Stewart Mountain dams increased the Association's electrical capacity nearly five times from eighteen thousand kilowatts to eighty-three thousand kilowatts, or from 25,000 horsepower to 111,000 horsepower. The maximum annual kilowatt hour production tripled from eighty-five million kilowatt hours prior to 1922 to 270 million kilowatt hours. Correspondingly, revenues increased from a maximum annual gross income of \$640,000 prior to 1922 to \$2.6 million with the hydroelectric additions.

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Arizona, Part II," 322-327; J. S. Connell, "Organization, Equipment and Methods, Building a Huge Irrigation and Power Project in Arizona," Contractors and Engineers Monthly 27 (August 1930): 55-60; and "Fourth Dam Built on Salt River, Water Users Finish \$2,300,000 Structure at Stewart Mountain, Adding 70,000 Acre Feet Storage and 15,000 H. P. to Electrical System," The Arizona Producer 9 (April 1, 1930): 1, 4. In March 1930 (volume nine) The Associated Arizona Producer changed its name to The Arizona Producer.

⁶History of the Salt River Project For the Period October 1, 1928 to September 30, 1929, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 10-11, and Chapter Six, "Power and Pumping Division," 10-11; History of the Salt River Project for the Period October 1, 1929 to September 30, 1930, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 13-14.

In addition to the mines, including Magma, Miami, Belmot, and Nevada Consolidated Copper, and CALAPCO, the Association provided electricity to portions of Phoenix and its neighboring communities, manufacturers, dairies, flour milling and ginning enterprises, irrigation and electrical districts, and its shareholders, over 3,300 by the end of 1930. The Association's system was also integrated with other electrical power producers. This enabled the Association to supplement its hydroelectric system, when needed, with power purchased from steam units operated by the mines, CALAPCO, and the Arizona Power Company. For the irrigation side of the project, the expansion plan developed nearly 650,000 acre feet of water enabling approximately 34,000 acres of previously unirrigated land to come into the project.

With the expansion plan finished, Frank Reid resigned as President of the Association. He chose not to seek reelection in April 1930. John H. Dobson of Tempe defeated Irving de R. Miller for Association President in a close election. On May 5, the day Dobson took office, and almost exactly ten years after he assumed office,⁸ Reid made his final address to the Association Board.

In reviewing his five consecutive terms as President, Reid highlighted many of his administration's accomplishments. Under his leadership, of course, Reid stated that the Association had dramatically increased its electrical revenues to the extent that shareholders' assessments would

⁷The History of the Salt River Project for the Period October 1, 1929 to September 30, 1930, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 7, and Chapter Six, "Power and Pumping Division," 2, 13. The 270 million kilowatt hours were generated in 1927-1928. The hydroelectric expansion program also added 1,150 miles of 110 KV power lines. Rural customers in 1922-1923 numbered fifty-seven and consumed \$4,571 in electricity. In 1929-1930 rural customers added \$250,000 to the Association's electrical revenues. History of the Salt River Project for the Period October 1, 1930 to September 30, 1931, Chapter Six, "Power and Pumping Division," 14. The extent and variety of the Association's electrical customers is best seen by filing through the eighty pages of customers the Association lists in its 1930-1931 annual history.

⁸"Water Users' Election," The Arizona Producer 9 (April 1, 1930): 3; "Dobson W. U. A. President," The Arizona Producer 9 (April 15, 1930): 6; "Dobson Heads W. U. A.," The Arizona Producer 9 (May 15, 1930): 2.

soon cease. "Something," he hoped, "[that] would come soon." The Association also reduced its gross operation and maintenance costs despite the addition in project acreage and the increase in water and power deliveries. Through his administration's drainage program, the project's groundwater table problem was relieved. Reid also added 180 groundwater pumps to the project, remedied many of Phoenix's flooding problems by supporting the 1922-1923 construction of Cave Creek Dam, improved the Association's canal and lateral system, and established solid lines of banking credit. After these many accomplishments, Reid felt it time he retire from the Association. Shortly after resigning, he moved to California where he became interested in farm and oil lands in the San Joaquin Valley.

Despite the successful completion of its hydroexpansion project, the Association unfortunately could take little satisfaction in its accomplishments. Before Stewart Mountain Dam was completed, the 1929 stock market crash caused a severe economic downturn in both the national farming and industrial economies. This resulted in the lowest level of prosperity among Valley farmers since the post-war 1920 depression. Gross crop returns for the project were forty percent less in 1930-1931 than the previous year. A severe drought also worsened conditions. Combined water storage for the Association's four dams in 1930-1931 equalled 150,000 acre feet, far below the their 1.7 million acre feet total capacity.¹⁰

The Depression also impeded full utilization of the Association's newly expanded power network. The failed national economy had a significantly adverse affect on central Arizona's power market. The electrical needs of Arizona's copper industry, always the Association's major electrical customer, lowered appreciably during the early 1930s. In 1929 state mines produced an income of \$226 million. By 1934 the economic downturn reduced that figure to \$15 million. This had a corresponding effect on the Association's kilowatt hour deliveries. In 1930-1931 the mines used ninety million kilowatt hours of Association

⁹F. A. Reid, "Old President's Statement, Review of 10 Years in W. U. A. History Shows Real Progress Made," The Arizona Producer 9 (May 15, 1930): 3, 5, 11. Reid died at the age of eighty-one years in 1961 in Bakersfield, California.

¹⁰Crop values fell from \$25 million in 1925 to a low of \$9.6 million in 1932. History of the Salt River Project for the Period October 1, 1930 to September 30, 1931, "Annual Report and Financial Statement," 3-4, 7.

power. In 1933-1934 they used twenty-three million kilowatt hours. Net Association power income plummeted from \$676,000 in 1929-1930 to \$61,000 in 1931-1932.¹¹

The losses in crop and electrical revenues through the 1930s caused the Association to fail again to meet its federal repayment obligations. In 1927 the Association did not meet its annual installment; however, in 1928 it made a double payment with money raised from the Stewart Mountain Dam bond issue. The Association fell delinquent again in 1930 because of the Depression. Under an agreement with the United States dated June 30, 1930, the Association was able to pay its 1929, 1930 and 1931 installments and lower its \$4.879 million federal debt by \$1.829 million by assuming a \$3 million refunding bond in 1930. The remainder of the bond went to pay outstanding short-term bank loans. After the Association met its 1929-1931 annual installments, subsequent payments were ostensibly deferred until 1937 by a federal reclamation relief act passed in 1932.¹²

In his 1932-1933 annual report, Harry Lawson, who replaced Charles Cragin as General Superintendent and Chief Engineer in May 1933, characterized the Association's harsh economic situation by writing, "So widespread and critical was the distress affecting people in all walks of life during the year just closed that old laws and practices broke with the strain." The only money the Association was able to raise was a \$880,000 loan from the federal relief agency, the Reconstruction Finance Corporation. This money was used to

¹¹A complete account of the Association's financial condition for this period is contained in Barry Dibble, "Engineering and Economic Examination of Salt River Valley Water Users' Association, Salt River Project," January 1935, 1-141, plus appendixes. Copy available at the Salt River Project Research Archives. History of the Salt River Project for the Period October 1, 1929 to September 30, 1930, Chapter One, "Annual Report of General Superintendent and Chief Engineer," 1-6, and Chapter Six, "Power and Pumping Division," 35-36; History of the Salt River Project for the Period October 1, 1934 to December 31, 1935, "Annual Report and Financial Statement," 1; and Chapter Six, "Power and Pumping Division," 45, 48.

¹²The \$3 million refunding bond was issued at six percent interest and due on November 1, 1956. Dibble, "Engineering and Economic Examination of Salt River Valley Water Users' Association," 36-37, 44-45. The Association obtained deferment under the Act of April 1, 1932, 47 Stat. 75, see Pelz, Federal Reclamation and Related Laws Annotated, 490-495.

support shareholders' farming operations and to retire part of \$1.059 million in bank notes. The sale of power was expected to make the dams self-supporting, repay the federal debt and the money borrowed for construction, pay for the operation of the irrigation system, and someday rid Association shareholders of acreage assessments. Instead, hydroelectric expansion costs, combined with the Depression, left the Association thoroughly plastered in bond indebtedness.¹³

If its failed financial condition did not cause the Association enough pain, newly-found technical problems at the dams compounded its suffering. Just three years after the Association completed Stewart Mountain Dam, consulting engineer William S. Cone found that the spillways for all four Salt River dams were inadequate. In a report requested by the Association's new General Superintendent, Cone wrote in July 1933 that the 1916 Salt River flood caused the canyon walls below the spillways at Roosevelt Dam to "disintegrate" to the extent that it was feared that the rock would "wear back the spillway crests." The flood releases also put the power house under seven feet of water making it inoperable. Spray also drenched all electrical apparatus and made it impossible to operate anything electrical within the area of the dam. Cone feared that

¹³ Harry Lawson was graduated from Purdue University in 1905 with a degree in electrical engineering. He worked for various electrical shops and companies until 1914 when he joined the Reclamation Service at the Salt River Project. He was the Association's power superintendent from November 1, 1917, the date the Association took over operations of the project. Lawson, however, did own farm land in the Valley since 1908. "Lawson Here Since 1908," Arizona Republic, May 2, 1933, 4. The Reconstruction Finance Corporation loan was fairly complicated. To obtain the loan the Association had to set up a subsidiary company called the Agricultural Credit Finance Corporation Ltd. because the Reconstruction Finance Corporation did not believe that it could lend money directly to the Association. For details, see Dibble, "Engineering and Economic Examination of Salt River Valley Water Users' Association," 50-54; History of the Salt River Project for the Period October 1, 1931 to September 30, 1932, "Annual Report and Financial Statement," 2-3; History of the Salt River Project for the Period October 1, 1932 to September 30, 1933, "Annual Report and Financial Statement," 1-2, 5-6.

another 1916 flood would cause equal if not greater damage at Roosevelt.¹⁴

Cone estimated that conditions would be as bad or worse after a similar flood at Horse Mesa, Mormon Flat, and Stewart Mountain dams. The south side cliff at Horse Mesa was already "badly seamed" and had begun to slide to the extent that the road to the south spillway was obliterated. To reach the top of the dam to operate the spillway gates, Cone commented, required one to "crawl over loose rock for some distance." To do this in heavy rain, Cone believed, would be "exceedingly dangerous." Additionally, Cone concluded that there was no way to get in or out of the Horse Mesa power house if the spillways were opened. At Mormon Flat the first opening of the spillway would immediately erode loose fill and cause it to pour into the power house, "probably wrecking the plant and making a prisoner of anyone who happened to be in there." In Cone's opinion, "the plant would be ruined with the first discharge of the spillways." The initial release at Stewart Mountain, Cone stated, would pour a gravel bank into the river directly in front of the power plant and probably clog the plant's draught tube.¹⁵

Cone concluded his inspection report by writing, "I am sure in my mind that a real menace exists, especially at Horse Mesa." He continued stating further that conditions were such that, "in some respects the possibilities of another St. Francis disaster are evident here." The St. Francis Dam failure had killed approximately four hundred people in California in 1928. If a flood of 1916 proportion occurred, not only would the power plants be taken out, but the cost in damages would equal, Cone said, a "very considerable sum of money." Beyond recommending that further examination of the spillways be made, Cone specifically advised that a method be devised for someone to escape from the Horse Mesa

¹⁴"Report on Inspection of Horse Mesa, Mormon Flat and Stewart Mountain Developments by Wm. S. Cone, July 21, 1933," 1-10, Record Group 115, Salt River Project Correspondence, 301-1, 1930-1945, National Archives, Washington D. C. Copy of report is available at the Salt River Project Research Archives. Greig Scott to Elwood Mead, August 16, 1933, Record Group 115, Salt River Project Correspondence, 301.1, National Archives, Washington D. C. Copy of letter available at the Salt River Project Research Archives. History of the Salt River Project for the Period October 1, 1932 to September 30, 1933, Chapter Two, "Engineering," 3.

¹⁵Ibid., 4-7.

power plant if the spillways were opened; the Mormon Flat spillway be rebuilt; and the spillway channel at Stewart Mountain be completed. Cone estimated that to repair the Association's spillways would cost roughly \$500,000.¹⁶

Cone's report was followed by two Reclamation studies made in 1934. The first report reviewed the Salt River's flood record, evaluated rainfall and runoff data, and calculated discharge amounts for an assumed flood based on the river's history. The report concluded that the project dams needed spillways capable of passing 175,000 cfs for extended periods, with the ability to pass 200,000 second feet in an emergency.¹⁷

The second report, completed in February 1935, was an inspection of all four dams made by Reclamation engineers D. C. McConaughy and R. S. Lieurance. After visiting Horse Mesa, these men concluded that the dam could not safely release any water from the left spillway, the one above the power plant. At the right spillway, they determined that the estimated capacity was appreciably lower than 65,000 to 70,000 cfs because of its narrow approach. At Mormon Flat, the engineers found that it "would be desirable to abandon the present spillway entirely." At Roosevelt, the spillway capacity should be increased; at Stewart Mountain, McConaughy and Lieurance decided that the spillway channel needed improvement, and better arrangements were necessary for opening the spillway gates.¹⁸

¹⁶Ibid., 8-10. For more on the St. Francis failure, see Charles F. Outland, Man-Made Disaster, The Story of St. Francis Dam, (Glendale, California: The Arthur H. Clark Company, 1963).

¹⁷E. B. Debler and H. J. Tebow, "Spillway Requirements, Salt River Project Dams," December 28, 1934, U. S. Bureau of Reclamation, 1-14, Record Group 115, Salt River Project Correspondence, 301-1, 1930-1945, National Archives, Washington D. C. Copy of report is available at the Salt River Project Research Archives.

¹⁸D. C. McConaughy and R. S. Lieurance, "Report on Stewart Mountain Dam, Mormon Flat Dam, Horse Mesa Dam, Roosevelt Dam, Salt River Project, Arizona," February 1, 1935, U. S. Bureau of Reclamation, 1-15, Record Group 115, Salt River Project Correspondence, 1930-1945, National Archives, Washington D. C. Copy of the report is available at the Salt River Project Research Archives. At Horse Mesa and Mormon Flat, the approach channels to the spillway gates were narrow and the spillway piers were set athwart or

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In their conclusions, McConaughy and Lieurance found that none of the four spillways met the 150,000 cfs estimate. At Roosevelt, discharge capacity was calculated between 113,000 cfs and 123,000 cfs; 105,000 cfs at Horse Mesa; 95,000 cfs at Mormon Flat; and 140,000 cfs at Stewart Mountain. At all dams except Roosevelt, spillway discharges would act to prevent access to the power plants. Plans to operate the spillway gates were inferior. At Horse Mesa, the only low level outlet was through the power unit which made proper operation of the reservoir inadequate. McConaughy and Lieurance recommended that for an estimated \$4.3 million, considerably more than Cone thought, all spillway capacities, spillway channels, and gate hoisting equipment be improved; safe access to the power houses and spillway gates be made; the left spillway at Horse Mesa be abandoned; and that both abutments at Horse Mesa Dam be grouted.¹⁹

Under prevailing economic conditions it was not likely that the Association could finance work to improve its spillways. It persuaded the Bureau of Reclamation, however, to perform the spillway work as part of the contract to construct Bartlett Dam on the Verde River. After years of conflict with the Verde River Irrigation and Power District, the Department of the Interior awarded the Association the rights to stored water on the Verde River. On November 26, 1935, the Association signed a contract with the Bureau of Reclamation in which the Bureau would construct Bartlett Dam on the Verde River approximately twenty-five miles above the Salt and Verde River confluence. The dam would store between 170,000 and 200,000 acre feet of water. Also included in the contract were provisions to improve the spillways at Roosevelt, Horse Mesa, Mormon Flat and Stewart Mountain dams. All the work would be funded under an interest free loan of up to \$6 million made to the Association by the Emergency Relief Appropriation Act of

(Footnote Continued)

obliquely to the line of water flow. The discharge capacity was impeded for these reasons.

¹⁹Ibid. For Horse Mesa and Mormon Flat, see F. L. Ransome, "Geological Report on Spillway Conditions at Mormon Flat and Horse Mesa Dams, Arizona," April 15, 1935, 1-11 with photographs. Copy available at the Salt River Project Research Archives. For Horse Mesa, see also E. C. Koppen, "Salt River Project, Horse Mesa Dam and Spillways," July 19, 1935. U. S. Bureau of Reclamation, 1-21, and following photographs. Copy of the report is available at the Salt River Project Research Archives.

1935, the Federal Emergency Administration of Public Works, or some other federal governmental program. ²⁰

The Bureau began spillway modification work at Stewart Mountain Dam in January 1936. It consisted generally of excavating and constructing a concrete spillway channel from the spillway to the river and installing new motors and hoisting mechanisms for operating the nine radial gates. Work at Roosevelt began in April. It entailed lowering the spillway crests six feet, strengthening the concrete piers, constructing concrete aprons below the crests, repositioning the radial gates, installing motors and hoists for each individual gate and two gasoline engine generators to operate the gate mechanisms independently. Work at both Stewart Mountain and Roosevelt Dam was completed by the end of the year. ²¹

²⁰"Contract Between the United States of America and the Salt River Valley Water User's Association Providing for the Construction of Bartlett Dam and Repairs to and Completion of Other Dams and Project Canals," November 26, 1935. Copy available at the Salt River Project Research Archives. History of the Salt River Project for the Period October 1, 1934 to December 31, 1935, Chapter Two, "Engineering," 5. The \$6 million loan was secured from the Public Works Administration. Association shareholders needed to ratify the contract, which they did on November 26, 1935. The contract also called for miscellaneous betterments to the project irrigation system and the rehabilitation of the Roosevelt Dam Power Canal and Diversion Dam. For information on the construction of Bartlett Dam, see E. C. Koppen, "Building Bartlett Dam," The Reclamation Era 30 (November 1939): 308-314.

²¹For accounts of the spillway modifications, the construction of Bartlett Dam, and the rehabilitation of the Roosevelt Power Canal and Diversion Dam, see E. C. Koppen, "Department of Interior, Bureau of Reclamation, Salt River Project, Arizona, Project History, 1935-1936," 1-69. Reprinted, without photos, in History of the Salt River Project for the Period January 1, 1936 to December 31, 1936. E. C. Koppen, "Department of Interior, Bureau of Reclamation, Salt River Project, Arizona, Project History, 1937," 1-106. Copy available at the Salt River Project Research Archives. Reprinted, without photos, in History of the Salt River Project for the Period January 1, 1937 to December 31, 1937. E. C. Koppen, "Department of Interior, Bureau of Reclamation, Salt River Project, Arizona, Project History, 1938," 1-106. Copy available at the Salt River Project Research Archives. Reprinted, without photos, in

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The contract for the spillway work at Horse Mesa was awarded to L. E. Dixon Company, Bent Brothers, and Case Construction Company, all of Los Angeles, in July 1936. Their bid of \$712,000 was the lowest received. The modifications consisted of two items: excavating a discharge tunnel; and modifying the spillways by constructing concrete aprons below the crests of both spillways, reinforcing the existing spillway gate piers, reconditioning and altering their position, and installing new operating equipment. Regrouting the foundation was considered originally as part of the work but was later abandoned. Work began in September 1936.²²

The contractors, with a work force of 250 men, started by erecting a construction camp which included a machine shop, compressor plant, and an aggregate processing plant. Preliminary activity also included improving the six mile road to the dam site from the Apache Trail. Excavating a 520 foot long tunnel with a 150 foot drop, the approach channel, and the gate house area began in October. The discharge tunnel was constructed to act as an auxiliary spillway. Work was started at both ends. At the downstream side excavation was carried to the tunnel's mid-point. Work at the upstream side was delayed because the tunnel entrance was realigned thirty feet soon after work began as a result of poor rock conditions. Tunnel excavation was thirty-six percent complete by the end of 1936.²³

(Footnote Continued)

History of the Salt River Project for the Period January 1, 1938 to December 31, 1938. See also "Bigger Spillways for Salt River Dams," Engineering News-Record (August 11, 1938): 174-177; J. A. Fraps, "Construction of Alterations to Spillway, Roosevelt Dam, Salt River Project, Phoenix, Arizona," June 24, 1937, 1-28 with photos and drawings; E. C. Koppen, "Construction of Spillway Channel, Stewart Mountain Dam, Salt River Project, Phoenix, Arizona," 1-23 with photos and drawings. Copy of both reports are available at the Salt River Project Research Archives.

²²Other contracts for the Horse Mesa work were awarded to the Commercial Iron Works of Portland for miscellaneous parts, to Consolidated Steel Corporation of Los Angeles for the discharge tunnel gate and frame, and to S. Morgan Smith Company of York, Pennsylvania, for delivery of the gate hoist.

²³The tunnel was elbowed twenty-seven degrees to allow water to discharge freely. For a complete account of the Horse Mesa work, see E. C. Koppen, "Final Report, Construction, Spillways for Horse Mesa Dam, Salt River

(Footnote Continued)

Because of difficult working conditions and the inability to install the fixed wheel gate at the entrance of the tunnel, the Bureau decided in January 1937 that it would be necessary to construct a coffer dam above the tunnel intake. A thirty-foot radius concrete arch dam measuring fifty-seven feet high and one foot thick was built while the reservoir level was down. The dam was constructed in vertical and horizontal sections. The horizontal joints were separated with tar roofing paper and a sheet of corrugated iron. Each lift or ring section was also jointed at the crown by a sheet of corrugated metal. Steel cables were attached to each block section. What leakage occurred was handled through a drain. When the tunnel was completed in September, the coffer dam was dismantled by removing and dropping the block sections into the reservoir. This building method enabled construction to progress without lowering the lake and affecting the output of hydroelectricity.²⁴

The remainder of the 42,000 cubic yards of excavated rock for the tunnel was removed after the coffer dam was finished in April. After excavation was completed, the tunnel was then lined with concrete which was prepared by two paving mixers moved as close to the point of placement as possible. Aggregate was obtained from a point about a quarter mile below the dam. Fresh concrete was poured using either buggies elevated on platforms or runways, or placed by pumpcrete. Concrete for all aspects of the project was

(Footnote Continued)

Project," September 20, 1938, U. S. Bureau of Reclamation, 1-41, including photographs and drawings. Copy available at the Salt River Project Research Archives. See also, "Increasing Spillway Capacities at Four Large Dams on the Salt River," Western Construction News 13 (November 1937): 453-456; "Bigger Spillways for Salt River Dams," Engineering News-Record 21 (August 11, 1938): 174-177; Richard T. Larsen, "Interesting Construction at Horse Mesa Dam," The Reclamation Era 28 (June 1937); and F. M. Shaw, "Final Inspection of Salt River Spillways," The Reclamation Era 29 (August 1938): 172, 175. "Project History 1935-1936," 40, 42, 44-45.

²⁴"Project History 1937," 46-47; E. C. Koppen, "Final Report, Construction, Spillways for Horse Mesa Dam, Salt River Project," 23-24; "Completing Horse Mesa Dam Spillways is a Big Job, Building 30-Foot Concrete Tunnel to By-Pass Water at 80 Miles an Hour," The Arizona Producer 16 (May 1, 1937): 10.

placed at night primarily²⁵ to maintain a specified temperature requirement.

The thirty foot diameter spillway tunnel was closed using a single, fixed-wheel steel gate measuring forty feet by forty-four feet and weighing 130 tons. The gate was installed against twenty-six roller bearings each weighing one ton. It was operated using a 114 ton counterweight which was installed in an operating room constructed above the channel intake. Materials for the gate house and all structural steel for the gate, gate operating machinery, reinforcement steel, and forms were conveyed from the north spillway deck to the tunnel inlet over a cableway.²⁶

Reconstructing the spillways and reinforcing the piers at Horse Mesa was performed in conjunction with the tunnel work. Apron work on the left or south spillway required particular care to avoid damage to the switching equipment on the roof of the power plant. Most of the excavation for the spillway aprons was completed by the end of 1936. The work required the removal of 6,000 cubic yards of rock. Pouring the concrete aprons and supporting piers was particularly slow going due to their position on the edge of the abutment cliffs. Reinforcing the piers was accomplished after the radial gates were repositioned by rotating them 180 degrees about their pivot pins.²⁷

Work at Horse Mesa Dam was completed in November 1937 but only after many difficulties. Beyond the considerable problems in performing the job and its extremely hazardous nature, coordinating the construction with the reservoir's operation proved impossible. While the work was progressing in June, the contractors were asked to complete the north or right spillway immediately because the project was suffering a water shortage. Water was released at 500 cfs on June 24, but it caused enough spray to put out the power house. Consequently, the contractor was directed to complete the discharge tunnel for service. From mid-August through most

²⁵"Project History, 1937," 47-48; Koppen, "Final Report, Construction, Spillways for Horse Mesa Dam, Salt River Project," 16-19.

²⁶"Project History 1937," 47; Koppen, "Final History, Construction, Spillways for Horse Mesa Dam, Salt River Project," 20-21; "Completing Horse Mesa Dam Spillways Is a Big Job," 10.

²⁷"Project History, 1935-1936," 44; "Project History, 1937," 47; Koppen, "Final Report, Construction, Spillways for Horse Mesa Dam, Salt River Project," 7-8, 21-22.

of September the tunnel was used to pass irrigation water. When the tunnel was closed on September 20, the contractors were able to complete the grouting work and paint the gate and gate machinery. The unanticipated water releases caused the contractor considerable delays, damage to equipment and material losses. These requests, combined with the nature of the work, left the Bureau's Supervising Engineer E. C. Koppen to conclude that the effect on the entire construction program left the contractors "demoralized" and generally made "an orderly and efficient plan impossible." The problems in completing the work were reflected in the final cost of \$1.16 million, significantly more than the \$712,000 bid. ²⁸

Despite the adversities, the rehabilitation to Horse Mesa Dam allowed the Association to pass 50,000 cfs through the discharge tunnel before opening any of the dam's gates. The spillway aprons worked to elevate the falling water so that the abutment walls were saved from erosion. ²⁹

The Bureau of Reclamation completed its Salt River Project spillway modification program at Mormon Flat Dam. As at Horse Mesa, the spillway piers at Mormon Flat were set athwart to the approach channel and therefore forced the water to make nearly a right angle turn to spill. This caused the water to pile up against the piers, impeding the success of the spillway. The Mormon Flat contract was awarded to Gunther and Shirley Company and J. P. Shirley, both of Los Angeles, for a bid of \$468,000. Generally, the contract specifications called for the complete removal of the existing spillway, constructing a concrete-lined channel, a gate superstructure, and a pair of fifty by fifty foot gates with necessary operating machinery. ³⁰

²⁸"Project History, 1937," 49.

²⁹Additional miscellaneous rehabilitation items consisted of filling sections of the left abutment with concrete, constructing a spiral stairway on the downstream face from the roof of the power house to the top of the dam, installing a drainage system in the tunnel and a crane in the gatehouse, and other minor items. Koppen, "Final Report, Construction, Spillways for Horse Mesa Dam, Salt River Project," 24; "Project History, 1937," 22.

³⁰For a thorough account of the spillway reconstruction at Mormon Flat Dam, see E. C. Koppen, "Final Report, Construction, Spillway for Mormon Flat Dam," November 15, 1938, U. S. Bureau of Reclamation, 1-27, including photographs and appendixes; "Project History, 1937," 55-57;
(Footnote Continued)

Gunther and Shirley moved to the site in March 1937 and began work by erecting camp accommodations for approximately thirty-five men. The camp included a mess, a powder house located about a half-mile below the camp, machine and carpenter shops, a small warehouse, and a cement shed. Only a small camp was constructed by Gunther and Shirley because many of the men housed themselves at tourist camps in the area and at the abandoned mining town of Goldfield. The Bureau and the Association constructed four permanent homes at the camp for use by Reclamation engineers and for later use by the Association's dam operators. The Association also moved its transformers from the power plant roof and rerouted its transmission lines away from the construction site.³¹

The contractors began work by removing the nine spillway gates, their concrete piers and deck, the spillway's west retaining wall, and other smaller associated pieces. Although the gates were initially stored for possible future use, they were later torched and junked. About 2,500 cubic yards of concrete were removed from the spillway structure and channel using a six thousand pound steel headache ball which was swung from a derrick. The construction specifications prohibited removing the spillway by blasting in order to maintain the integrity of the dam.³²

After the removal of the gate works, a concrete arch coffer dam was constructed to permit operation of the lake independent of construction. The Association petitioned the Bureau to add a coffer dam as an extra construction item because it calculated that it could generate \$50,000 in electrical revenue if it kept the reservoir full through the 1937 calendar year. The Association also calculated that a coffer dam would cost \$15,000, an expense it gladly agreed to remit. The dam was built in sections, much like the one at Horse Mesa. Each four foot lift was separated by tar paper and vertical sections were separated using corrugated metal and fitted with lifting lugs. The dam was completed in July. At this time water was being released from Horse Mesa into the Mormon Flat reservoir to meet the irrigation demand. But the difficulty in passing water through Horse

(Footnote Continued)

"Project History, 1938," 19, 62-68; and Allen Mattison, "Spillway Reconstruction at Mormon Flat Dam," The Reclamation Era 29 (May 1938): 94-95.

³¹Koppen, "Final Report, Construction, Spillway for Mormon Flat Dam," 5-6; "Project History, 1938," 63.

³²Koppen, "Final Report, Construction, Spillway for Mormon Flat Dam," 7.

Mesa's north spillway and tunnel, combined with the continuous release of water from Mormon Flat, caused the Mormon Flat reservoir level to fall rapidly. The quick drop of water behind the cofferdam, added to the weight of debris and water collected on the coffer dam's downstream side, caused the dam's right side to fall into the reservoir, leaving the structure useless. After considerable review and discussion with the Association, it was decided to abandon the coffer dam and require the Association to keep the reservoir elevation sixty-one feet below the dam's crest elevation. ³³

Excavation of the spillway channel began in early summer. Work was started on the upstream end of the channel to expedite the construction of the gatehouse and spillway gates and to attempt to accommodate the water storage demands of the Association. This work was accomplished using explosives. Considerable care, however, was taken in the use of powder to prevent damage to the dam's left abutment, the power house, its windows, the penstocks, pumps, and any other exposed structures or equipment. Quantity of powder, method of detonation, and the number of holes per round were strictly controlled. The excavated rock, about 70,000 cubic yards, was either dumped or spoiled in the river channel downstream, in a nearby ravine, or hauled upstream and deposited in the reservoir. ³⁴

The new spillway channel was designed to curve roughly on the same radius as the dam. It was built 450 feet long, 100 feet wide at the crest and tapered to a width of 45 feet. The elevation of the channel at the crest is 60 feet below the top of the dam and drops 53 feet to its outlet. The sidewall lining is sloped and rises 50 feet above the channel floor. Subchannel drains were included to protect against potential uplift pressure. ³⁵

³³Ibid., 10-11; S. O. Harper to Elwood Mead, May 20, 1937, Record Group 115, General Administrative and Project Records, 1930-1945, 301.14, Salt River, National Archives, Washington D. C. Copy of letter is available at the Salt River Project Research Archives. The actual cost of the coffer dam was \$16,800.

³⁴Koppen, "Final Report, Construction, Spillway for Mormon Flat Dam," 8-9. 11-12; Mattison, "Spillway Reconstruction at Mormon Flat Dam," 95.

³⁵Koppen, "Final Report, Construction, Spillway for Mormon Flat Dam," 14-15; Mattison, "Spillway Reconstruction at Mormon Flat Dam," 94-95.

The construction concrete plant was located above the channel's left wall. Aggregate was hauled by truck from about a half-mile downstream to the batch plant and processed into bunkers. Fresh concrete was prepared in a one-yard mixer and dumped into cubic yard buckets on a flatrack truck. The truck hauled the concrete to cranes which hoisted it into place. Channel construction required about three thousand cubic yards of concrete.³⁶

About ten thousand cubic yards of concrete were used to reconstruct the spillway crest and the gate superstructure. The gate house rises 134 feet above the spillway crest and supports the two, fifty by fifty foot spillway gates. Installing the million pounds of gate steel work was completed after some difficulty. It was found that although the gates and frames were shop assembled, many of the components were in generally bad condition, either poorly fitted, wavy, badly warped, twisted or requiring extra bracing. Many of the rivet holes were misaligned. The gates were erected before the towers supporting the gate house were poured. The gate house included six gasoline engines so that gates could be operated at all times. The spillways were counterbalanced so that a small, 7.5 horsepower motor could operate them.³⁷

Two additional items were included in the Mormon Flat reconstruction. As the work progressed, the Bureau learned that the tension on the upstream face of the dam could possibly tip the left or south abutment or ogee section into the spillway. Consequently, the abutment was reconstructed as a thrust block by overlaying 3,200 cubic yards of concrete to the section. This offset the abutment tension and the tendency of the abutment or ogee to tip by the addition of more weight. The thrust block was strengthened further by anchoring the section using reinforced steel. The final construction item called for rebuilding the roadway to the power plant.³⁸

³⁶Ibid.

³⁷Koppen, "Final Report, Construction, Spillway for Mormon Flat Dam," 15-17. The spillway gates were manufactured by the American Bridge Company of Ambridge, Pennsylvania. The gate hoists were finished by the Consolidated Steel Company of Los Angeles.

³⁸Mattison, "Spillway Reconstruction at Mormon Flat Dam," 95; Koppen, "Final Report, Construction, Spillway For Mormon Flat Dam," 17-18. Miscellaneous construction items included grouting work, installing two spiral stairways and a domestic water supply.

Work at Mormon Flat Dam was completed in June 1938. Total cost for rebuilding the spillway was \$938,000, twice the contractor's bid. Most of the additional cost, \$299,000, was in material furnished by the government. The remainder was in miscellaneous fees including \$117,000 in engineering and inspection expenses. The cost for the spillway improvements at all four Salt River dams equalled \$2.766 million.³⁹

The completion of work under the 1935 contract could not have been timed better. The Association benefitted from the improvements almost immediately. Although Bartlett was not fitted with a hydroelectric unit, stored water on the Verde River enabled the Association to generate more hydroelectric power on the Salt. In the winter of 1940-1941, the second winter after the work was finished, central Arizona received over twenty inches of rain or three times its annual sum. This filled all the Association's reservoirs which were nearly dry after a severe drought. The record amount of winter precipitation also caused the dams to spill water, which they safely did, in April and May of 1941. Bartlett's completion was also fortuitous for the Association because World War II tremendously spurred central Arizona's farming, mining, and industrial economies. America's war effort maximized the Association's power system's capacity. For four of the five war years, the Association generated and purchased for resale over six hundred million kilowatt hours annually or enough power to net the Association millions of dollars in electric power revenues.⁴⁰

Through the war years and beyond, all Salt River dams performed without incident. They operated successfully, storing water and generating hydroelectricity. Other than general annual maintenance, no major work on the structures was performed. However, since the 1930s spillway modification program to 1988, two programs have improved the

³⁹Koppen, "Final Report, Construction, Spillway for Mormon Flat Dam," Appendix, "Costs and Quantities."

⁴⁰The Association generated hydroelectric, steam, diesel and purchased power. For example, in 1945 the Association produced 344 million kilowatt hours in hydroelectric power, 89 million kilowatt hours in steam, 13 million in diesel, and purchased 265 million in purchased power. History of Salt River Project for the Period January 1, 1945 to December 31, 1945, "Annual Report and Financial Statement," 5, and Exhibit B. For further information on the Association's economic status during this period, see Raymond A. Hill, "Economic Survey of Salt River Project, Arizona," September 1942, 1-135 plus appendixes.

dams' physical facilities and hydroelectric output. Under the federal Rehabilitation and Betterment Act of 1949, upgrades were made at the dams in the 1950s to improve their operation. Under another program conducted in the 1960s and early 1970s, the Association increased the dams' hydroelectric generating capacity, converting their output from twenty-five cycles to sixty cycles, and then Mormon Flat with pump back capability.

In 1949 Congress authorized legislation providing reclamation projects with low interest bearing funds to restore worn and dilapidated irrigation structures. Under this legislation, called the Rehabilitation and Betterment Act, the Association borrowed \$27 million over three decades primarily to improve its water distribution system. The money was used to pay for lining and piping many of the Association's canals and laterals and for replacing wooden canal gates with more durable steel gates. The Association also performed maintenance items at its dams with monies from the Rehabilitation Act. At Mormon Flat Dam, the Association reconstructed the dam's access road, rebuilt the operators' residences, repaired the camp's water supply, and cleaned and coated the dam's penstock. At Horse Mesa, the spillway tunnel's fixed wheel gate had developed serious leaks. It was sand blasted, resealed, and given a protective water proof coating.⁴¹

The second improvement, called HEFU or Hydro Expansion and Frequency Unification, was undertaken to increase the hydroelectric capabilities at Mormon Flat, Roosevelt, and Horse Mesa, to complete the conversion of the Association's electrical system to sixty cycle electrical power, and to provide a more firm power load. Beginning in the early 1940s, the Association realized that twenty-five cycle compared to sixty cycle electrical power was becoming obsolete. This was primarily because twenty-five cycle power produced a perceptible flicker in lighting and cost the consumer more in electrical equipment. Of all the

⁴¹"Rehabilitation and Betterment Act," October 7, 1949, 63 Stat. 724. See Pelz, Federal Reclamation and Related Laws Annotated, vol. 2., 969-971, and U.S. Congress, House, Committee on Public Lands, Providing for Return of Rehabilitation and Betterment of Costs of Federal Reclamation Projects: to Accompany H.R. 1694, Rept. 589, 81st Cong., 1st Sess., May 16, 1949. For a complete history of the Salt River Project rehabilitation and betterment effort, see Jay C. Ziemann, "The Modernization of the Salt River Project: The Impact of the Rehabilitation and Betterment Program" (M. A. thesis, Arizona State University, 1987).

Association power plants, which now included three Valley steam plants, only the Salt River hydroelectric units were not producing sixty cycle power in the 1960s.⁴²

The only remaining large Association customers of twenty-five cycle hydroelectric power in the 1960s were three copper mines: Inspiration, Miami, and Magma. The Association served most of their load with sixty cycle steam or thermal generated power. This power was converted to twenty-five cycles by frequency changers located in the east Valley. Summer peak demand, however, was met with hydroelectricity. The problem in meeting the mines' demand, particularly in the summer, was that the Association's frequency changers could not convert more than 30,000 kilowatts of sixty cycle power at any one time and it could only count on firm twenty-five cycle hydroelectric production generally during the summer when water was run for irrigation. These factors, combined with the mines annual electrical load growth of 2.7 percent, made it increasingly difficult for the Association to meet the mines' twenty-five cycle load. The Association provided a short term remedy to the problem by converting a sixty cycle, 7,500 kilowatt steam unit to twenty-five cycles. This served, however, as only an interim measure. The Association realized that the time had come for it to overhaul its hydroelectric system.⁴³

In 1966 the Association determined that it could feasibly increase its Salt River hydroelectric capacity at Roosevelt, Horse Mesa, and Mormon Flat from 60,000 kilowatts to 196,000 kilowatts at sixty cycles. It could do this by rewinding the existing units to sixty cycles at Mormon Flat and Horse Mesa, and adding new sixty cycle units at Roosevelt, Horse Mesa, and Mormon Flat. Stewart Mountain Dam had already

⁴²Raymond Hill noted in his 1942 report to the Association that "25 cycle power systems are now nearly obsolete." Hill, "Economic Survey of Salt River Project, Arizona," 32. The Association completed Crosscut Steam Plant in 1949, Kyrene Steam Plant in 1954, and the Agua Fria Steam Plant in 1961. Combined capacity in 1961 at these three plants was approximately 535,000 kilowatts.

⁴³T. M. Morong, E. J. Lauerma, J. A. Hollewell, "The Salt River Project's Hydro Expansion and Frequency Unification Program," paper presented to the Institute of Electrical and Electronics Institute, Phoenix, Arizona, April 18, 1969, 136-137; J. George Thon, John W. O'Hara, and C. H. Whalin, "Modernization of Dams on the Salt River," paper presented to the American Society of Civil Engineers, New Orleans, Louisiana, February 4, 1969, 1-25.

been converted to sixty cycles in 1962. The rewound units at the three dams would produce 43,000 kilowatts and the new units would generate 153,000 kilowatts.⁴⁴

After internal review, the Association consulted with the Bechtel Corporation of San Francisco in 1967 to evaluate replacing the generating turbines at the three dams and to reconfigure the transmission facilities to complement the hydro conversion and enlargement. The Bechtel study recommended that the Association convert its plants from twenty-five to sixty cycle, increase the capacity of the three hydroelectric plants to 186,000 kilowatts, modify the Association's transmission and communication system, and have the copper mines' loads adapt to a sixty cycle power supply. The Bechtel report also argued for installation of reversible pump-turbine units at Horse Mesa and Mormon Flat to obtain increased capacity and to firm winter generating capability. Reversing the turbines during off-peak hours would enable the Association to recapture used water for regeneration.⁴⁵

The Bechtel report concluded that both the Association and the copper mines would realize several significant benefits by implementing the modifications. The Association stood to gain because the conversion would eliminate the need for frequency changers and the restrictions they imposed on the system. It would also rid the system of multiple transmission lines to the mines. Maintenance and repairs costs would be reduced, and operations would be made more efficient if the technology operating the hydroelectric units was automated from Phoenix. For the mines, the report stated that they would experience increased reliability and stability through the elimination of the frequency changers and multiple transmission lines. Equipment life would be extended through replacement and maintenance and repair

⁴⁴Morong, Lauerman, and Hollowell, "The Salt River Project's Hydro Expansion and Frequency Unification Program," 137. See also the studies made by the Association's System Planning Department listed in A. L. Schwalb to File, "Pow 6-5, Freq. Unification - Basic Data - Etc," Box 115, Salt River Project Research Archives.

⁴⁵Bechtel Corporation, "Frequency Unification and Hydro Extension Study for Salt River Project," 1967. Copy of report is available at the Salt River Project Research Archives. It takes approximately one hundred kilowatts of power to capture enough water to regenerate seventy kilowatts of electricity. However, the availability and cost of electrical energy during off peak-hours makes the reverse turbine technology profitable.

costs would be reduced through the use of sixty cycle equipment.⁴⁶

Bechtel estimated the conversion would cost the Association \$22.3 million, and the mines \$6.2 million. It compared the Association estimate with two alternatives: maintaining the present twenty-five cycle system, and purchasing available alternative power. Over a projected forty year period, Bechtel concluded that the Association would save \$14 million over continuing to use twenty-five cycle power and \$12 million over purchasing electricity from gas-fired plants. The \$6.2 million cost to the copper mines, Bechtel estimated, would also be less over time. Calculating losses and replacement values, Bechtel concluded that over ten years the mines would save \$1.2 million by upgrading their systems.⁴⁷

Having concluded the program had both operational and economic justification, the Association adopted the HEFU project. This included the reversible pump-turbine units which made the Association the first utility in the Southwest with a pumped storage generating system. After the Bureau of Reclamation reviewed the modifications in the spring of 1967, the Association signed a contract with Bechtel to construct the HEFU plan in January 1969.⁴⁸

HEFU construction began at Mormon Flat Dam. After the reservoir was emptied and Stewart Mountain Dam's reservoir lowered in the summer of 1969, an eighteen foot diameter tunnel was cut through the dam. The new penstock opening was connected to a 44,000 kilowatt reversible pump unit installed in a concrete block structure just downstream from the existing power house. This was controlled using a wheeled gate on the upstream face of the dam. The existing

⁴⁶Bechtel, "Frequency Unification and Hydro Extension Study for Salt River Project," 2-1 to 2-13.

⁴⁷Morong, Lauerman, and Hollowell, "The Salt River Project's Hydro Expansion and Frequency Unification Program," 137-138; Bechtel, "Frequency Unification and Hydro Extension Study," 2-10 to 2-13 and 8-16.

⁴⁸C. H. Whalin to T. M. Morong, April 5, 1967, File, "25 Cycle Study, Letters - Reports," Box 117, Salt River Project Research Archives. "Construction Contract Between Salt River Project Agricultural Improvement and Power District and Bechtel Corporation for Salt River Hydro Expansion and Frequency Unification," January 24, 1969, 1-38 plus appendixes, File, "Construction Contract, HEFU," Box 120, Salt River Project Research Archives.

penstock and scroll case was rehabilitated and repaired. Its intake was modified using two more wheeled gates which were also installed with a hydraulic hoist located at the top of the dam. The existing twenty-five cycle turbine was rebuilt for service at sixty cycles. Its capacity remained at 10,000 kilowatts. All existing switchyard equipment was modified as required. ⁴⁹

Coincident to completing the work at Mormon Flat Dam in 1970, the reservoir behind Horse Mesa Dam was drawn down and work began there. The three existing hydraulic turbines, spiral cases, draft tubes, penstocks and ancillary equipment were rebuilt for service at sixty cycles. Each maintained their capacity of 10,000 kilowatts. The new, 67,000 kilowatt reversible pump turbine facility was also constructed below the existing power plant. It was served by a 15.6 foot diameter penstock drilled through the dam face. The new penstock was operated using a wheeled gate on the upstream face of the dam. ⁵⁰

The HEFU project was completed in 1973 with work at Roosevelt Dam and along the Association's transmission lines. All twenty-five cycle turbines and generators at Roosevelt were dismantled and replaced with one, sixty cycle, 36,000 kilowatt unit located on an outside deck attached to the power plant. All control equipment was removed from the control room and replaced. The Association's 110 KV, twenty-five cycle transmission system from Horse Mesa to the Goldfield Switching Station was upgraded to 115 KV, sixty cycle to accomodate the new generation. The new line was constructed using wood "H" frame poles. Three new switching stations were also added. Finally, all new units were fitted with propane-driven motors which enabled the hydroelectric system to cold start in the event ⁵¹that power from a Phoenix thermal plant was unavailable.

From Reclamation's spillway reconstruction in the 1930s and the Association's HEFU modifications in the late 1960s and early 1970s, betterments continue to be made to the Salt River dams. Under the Bureau of Reclamation's Plan 6 program and the federal Safety of Dams Act all Salt River

⁴⁹Thon, O'Hara, and Whalin, "Modernization of Dams on the Salt River," 16-19.

⁵⁰Ibid., 19-21; File, "Salt River Hydro Pump-Back Storage System," Box 112, Salt River Project Research Archives.

⁵¹Ibid.

Project dams will be rehabilitated beginning in 1988. The least appreciable work will be done at Mormon Flat and Horse Mesa dams. These structures will not be changed in dimension or operation but will be strengthened against potential seismic activity using steel ties drilled and bolted through the dam face and abutments and anchored into the foundation and canyon walls. Roosevelt Dam will be raised approximately seventy feet and Stewart Mountain Dam will receive a long list of upgrades including a new spillway at its right abutment.

Chapter Six: Conclusion

After more than a decade of economic drift the Association's hydroelectric expansion program realized its full potential beginning in 1941 when America entered World War II. The war effort rejuvenated central Arizona's copper and farming industries. Though copper mining did not approach its 1929 production of \$226 million, it improved dramatically from mid-1930s levels. By 1944 the valuation of producing copper mines in the state had risen to \$133 million. This amount marked a vast improvement from the Depression low of \$15 million mined in 1934. In farming, Project crop production and stock raising produced record receipts of \$36 million in gross revenues in 1944.¹

Central Arizona's wartime farming and industrial boom was fueled, in large part, by the Association. In 1943 it delivered 602 million kilowatt hours of electricity. Power was generated from its hydroelectric plants, supplemental oil and diesel steam units located at its Cross Cut hydroelectric plant, and power it purchased from CALAPCO and the mines. This was twenty percent more energy than the entire state produced in 1920, almost four times the amount the Association produced in 1932, its Depression-era low, and 100₂ million hours beyond its previous peak production level.²

Other war industries were also fueled by the Association. Because of Arizona's remote location and its clear and dry weather, the Valley became a center for wartime training and military electronics production. The federal government authorized creating three army camps and six air bases in

¹History of the Salt River Project for the Period, January 1, 1944 to December 31, 1944, Chapter One, "Report of General Superintendent and Chief Engineer," 1, 3-4. The worst agricultural year during the Depression, 1932, project crop receipts equalled \$9.6 million.

²History of the Salt River Project for the Period January 1, 1945 to December 31, 1945, Chapter One, "Annual Report and Financial Statement," 4-5. The Association produced 164,000 kilowatt hours in 1932. Prior to 1943 the Association's previous kilowatt hour peak was reached in 1942 when it generated 516 million kilowatt hours. In 1944 and 1945 the Association produced over 700 million kilowatt hours. See tables giving delivery of kilowatt hours for the period 1940 to 1945 and revenue from sale of power for these years at pages 91 and 92 in Chapter Six, "Power and Pumping Division."

the Valley by 1942. The electronics industry, led by Motorola, AiResearch, General Electric, Kaiser Aircraft and Electronics, Goodyear Aircraft, and Sperry Rand, located in the Valley because, among other reasons, they needed a dry climate to manufacture precision electronic components.³

The Association served these industries in addition to the mines, municipalities, utilities, electrical districts, industrial manufacturers, farm industries, gins, and rural consumers, who numbered over ten thousand by 1945. Power receipts, along with acreage assessments, which were never dropped despite Reid's firm belief, brought the Project out of the persistent annual net losses of the early 1930s. From 1940 to 1945, the Association experienced a strong recovery,⁴ earning well in excess of \$5 million in net profits.

Unlike the depression which followed the conclusion of World War I, the Valley economy did not retract after World War II. There was no postwar calamity reoccurrence. Valley farmers did not again become intoxicated with the possibility of cotton profits, but even if they had, industry in central Arizona had become too diverse and enveloped in the national market by the end of World War II for the Valley to be shocked again by a single event. For example, even at the outset of America's involvement in World War II, the Phoenix metropolitan area was home to 1,200 retail stores and eighty manufacturing concerns.

By the conclusion of the war non-mining industries had developed to such an extent that by 1945 both municipalities and utilities and irrigation pumping had surpassed mining's electrical usage. The rural domestic electrical market also continued to expand, consuming thirty million kilowatt hours, an increase of five hundred percent from 1935. During the 1940s another industry had blossomed in the Salt River Valley. Renamed the Valley of the Sun by local publicists, Phoenix and the surrounding communities were attracting over 50,000 tourists and vacationers each winter

³Bradford Luckingham, The Urban Southwest, A Profile History of Albuquerque, El Paso, Phoenix, Tucson (El Paso: Texas Western Press, 1982), 78-84.

⁴History of the Salt River Project for the Period October 1, 1934 to December 31, 1935, Chapter One, "Annual Report and Financial Statement," 8; History of the Salt River Project of the Period January 1, 1945 to December 31, 1945, Chapter One, "Annual Report and Financial Statement," 13.

after the war. Finally, technological advancements made in air conditioning made possible "climate control," encouraging more businesses to move to Arizona. The postwar boom was aptly and succinctly summed up by Harry Lawson when he commented in his 1945 annual report, "Postwar conditions in the area have become amazing."⁵

From the postwar era to 1988, central Arizona's economy has continued to grow at a dramatic if not stunning rate. Between 1940 and 1960 the population of Phoenix increased from 65,000 to 439,000. The neighboring communities of Mesa and Glendale, for the same period, increased from 7,000 and 4,800 to 149,000 and 92,000 respectively. From \$36 million in farming production in 1944, Valley farmers increased production value to \$155 million in 1954 and to \$418 million by 1974. Phoenix's manufacturing output of \$4.8 million in 1940 rose by staggering percentages to \$115 million in 1954 and to \$435 million in 1963.

The extent of economic growth had a corresponding effect on the Association's electrical production: output increased to 900 million kilowatt hours by 1950, 2.7 billion kilowatt hours in 1960, and to 5.3 billion kilowatt hours in 1970. The Salt River Project along with CALAPCO's successor, Arizona Public Service, provide most of the electric power to the city of Phoenix, which in 1988 has become the twenty-first most populated city in the U.S., the seventh largest city in land area with 386 square miles, and the ninth most densely populated metropolitan area in the nation.⁶

The growth of central Arizona's economy can be attributed in large part to Frank Reid and Charles Cragin. The construction of Roosevelt Dam on the Salt River by the federal government permitted the sustained and successful settlement of the Phoenix area. But it was the contribution of hydroelectricity that permitted central Arizona to advance far beyond its agrarian base. It was hydroelectricity that provided the Salt River Valley with the catalyst for further and fuller economic growth.

⁵History of the Salt River Project for the Period January 1, 1945 to December 31, 1945, Chapter One, "Annual Report and Financial Statement," 5.

⁶Luckingham, The Urban Southwest, 82, 86, 99. For annual kilowatt hour production for 1950, 1960, and 1970, see Salt River Project Annual Reports for those years. Copies are available at the Salt River Project Research Archives.

Cragin's hydroelectric expansion made its greatest contribution to Arizona mining. It allowed the copper mines to become the state's largest industry. The technology to purify copper is essentially electrolytic: suspended copper particles plate in pools of electrically charged, ionized water. Copper production is economically possible only if a cheap power source is available. Association hydroelectricity met mining's needs fueling an activity which has contributed billions of dollars to the national and local economy. Copper mining in Arizona has produced over 350 million tons of ore and six⁷ billion pounds of copper valued at over \$1.1 billion.

While contributing to mining and other industrial enterprises, the Association's rural electrification program made a significant social impact. It made possible the service of electricity to every farm. This component of the expansion activity was perhaps the most forward thinking aspect of Cragin's work. He formed his plan to bring electricity to rural domestic users more than ten years before the federal government formed the Rural Electrification Administration (REA) in 1935. In the mid-1920s less than three percent of America's 6.4 million farms received electricity despite the fact American farmers used twice the primary power of all U.S. factories combined. By April 1930 eighty percent of all homes on the Salt River Project had been connected with electrical service.⁸

On a national scale much was expected of rural electrification. Scholars, politicians, and social reformers eagerly anticipated the impact "Giant Power" presented. In 1924, Lewis Mumford, the social theorist, predicted that the technology of electrical generation and transmission, along with the automobile, radio and telephone, would cause the fourth great movement or migration in American civilization. It would be the basis of what he termed the neotechnic age, a period cured of many social problems. Gifford Pinchot, Governor of Pennsylvania and former Chief of the U.S. Forest Service, predicted in 1924 that "Giant Power," a phrase he coined, would provide "the most substantial aid in raising the standard of living, in eliminating the physical drudgery of life, and in winning

⁷Frank Tuck, Stories of Arizona Copper Mines, (Phoenix: Arizona Department of Mineral Resources, 1957), 22. See also Charles H. Dunning, Rock to Riches (Phoenix: Southwest Publishing Company, 1959), 304-314.

⁸C. C. Cragin, "Development of Hydro-Electric Power as an Aid to Irrigation," 553-554.

the age-long struggle against poverty." In retrospect, the electrical age did not radically change societal conditions and whether Cragin was motivated by these expectations for universal electrification is difficult to determine.

For the Association, electrical expansion radically changed its character. While most federal reclamation projects generally, if not exclusively, remained irrigation works, the Salt River Project rapidly developed a dual nature. By pioneering a power side to its operations, the Association was able to accomplish several goals. The sale of hydroelectrical power carried a significant share of the Association's federal repayment obligation for the Salt River Project's initial construction charges. Hydroelectric revenues gave the Association monies to sell more power than it generated by retailing purchased steam power from other local producers. It also provided the Association with revenue to operate and maintain its lengthy water and power transmission and delivery system. Hydroelectric power availability enabled it to supplement its surface water supply using groundwater pumps. It also drained groundwater in areas where shallow subsurface water endangered crop success. The construction of power dams added additional stored water enabling the project to increase its irrigable acreage. Finally, the proximity of its last hydroelectric dam at Stewart Mountain permitted the Association to respond more rapidly in meeting water orders and better regulate the river.

⁹A national program of rural electrification began in 1935 when the Roosevelt administration created the Rural Electrification Administration under the 1935 Emergency Relief Appropriation Act. For a thorough discussion of "Giant Power" and universal electrical service, see: Robert W. Bruere, "Pandora's Box;" Gifford Pinchot, "Giant Power;" Philip P. Wells, "Our Federal Power Policy;" Alfred E. Smith, "The State of the Public;" William Hard, "Giant Negotiations For Giant Power, An Interview with Herbert Hoover;" Philip Cabot, "National Electrical Highways;" Martha Bensley Bruere, "Following the Hydro;" H. G. Butler, "Pools of Power;" Joseph K. Hart, "Power and Culture;" Gerard Swope, "The Engineer's Place in Society;" Lewis Mumford, "The Fourth Migration;" Lewis Mumford, "Regins - To Live In;" and Robert W. Bruere, "Giant Power - Region-Builder;" all are contained in The Survey 51 (March 1, 1924): 557-640, 652, and The Survey 54 (May 1, 1925): 129-133, 151-152, 161-164. For an assessment of the failure of the electrical age, see Thomas P. Hughes, "The Industrial Revolution That Never Came," American Heritage of Invention and Technology 3 (Winter 1988): 59-64.

Experience the Association gained through the Cragin's constructions and in subsequent electrical manufacturing gave it the precedent, knowledge, and confidence to expand its power grid when the load demanded additions. From 1949 through the 1980s the Association has continually enhanced its generating capacity through construction and participation in developing steam and nuclear units in Arizona and throughout the Southwest. While still a major supplier of developed surface and groundwater in central Arizona, the long evolution of Salt River Project's power development has made it, in 1988, the third largest municipal utility in the nation, with the capacity to generate over two million kilowatts or two thousand megawatts at peak load. As a financial entity the Salt River Project operates a billion dollar annual budget in 1988-1989, over 95 percent of which is earned through the sale of electricity.¹⁰

While the hydroelectric expansion plan was conceived and constructed by the Association, it did ultimately have a substantive influence on federal reclamation efforts. The Salt River Project demonstrated the financial success a federal reclamation project could enjoy if it combined hydroelectric power with irrigation water storage and delivery.

In 1923 the professional engineering journal, Engineering News-Record ran a nine-part series of articles titled, "Federal Land Reclamation: A National Problem." Authored by prominent engineers and state and government officials, the series highlighted the multitude of difficulties the national reclamation program experienced. In the series' first article, Frederick H. Newell, former Director of the Reclamation Service, saw national reclamation efforts under the 1902 act nearly at an end. He wrote, "The present time is appropriate for a review of its operations because of the fact that its history is now practically a closed chapter." Newell wrote this because he and the series' subsequent authors identified the many economic and social problems the reclamation program experienced. They identified the program's political, legal, financial, and management imperfections, obstacles, and limitations and the difficulties involving repayment, irrigation methods, land

¹⁰The Salt River Project ranks third in size behind Los Angeles Department of Water and Power and the Puerto Rico Electrical Power Authority.

speculation, farm financing and¹¹ farming experience, and soil and water logging conditions.

Presumably the intent of the series was only to identify reclamation's shortcomings. No solutions were offered to improve national reclamation policy. It is interesting that no mention was made of hydroelectricity nor its use as a possible solution to reclamation hardships.

Three years after the Engineering News-Record series, The New Reclamation Era, the federal government's official Reclamation publication, only marginally recognized the potential for hydroelectricity. Written in an article titled, "Electric Power Development on The Projects" was the statement, "The construction of dams to store and divert water for irrigation has afforded an opportunity for the development of hydroelectric power as an incident to irrigation" (emphasis added). After stating that thirteen federal reclamation projects grossed \$1.067 million for 1925, the article concluded, "this satisfactory financial showing is, however, the least part of the benefit" (again emphasis added). "The chief gain," the article concluded, "has come from having this cheap power to operate pumping plants to furnish irrigation water; [and] to use as motive power for drag-line excavators, both in building and cleaning out canals and drains." Six years later in 1932 the combined hydroelectric output of all twenty hydroelectric power plants on eleven of the twenty-nine reclamation projects (excluding the Salt River Project) generated 102,000 kilowatts earning a net income of slightly more than \$400,000. In 1932 the Salt River Project alone

¹¹Under the title, "Federal Land Reclamation: A National Problem," Engineering News-Record ran the following articles: F. H. Newell, "Origin, Problems and Achievements of Federal Land Reclamation;" C. E. Grunsky, "The Development of the West Under Irrigation;" Carl S. Scofield, "Agriculture on Irrigated Lands;" F. H. Newell, "Twenty Years of Reclamation;" George C. Kreutzer, "After Reclamation, Organized Land Settlement;" H. H. Brook, "Difficulties and Complaints of the Farmer;" James T. Whitehead, "Financial Troubles of the Reclamation Farmer and How They May Be Relieved;" Thomas H. Means, "Faults of Reclamation Law and Practice, and Their Remedies;" and Addison T. Smith, "The Future of Federal Reclamation," Engineering News-Record 91 (October-December, 1923): 666-673, 715-718, 756-761, 801-807, 838-841, 890-892, 924-925, 977-981, 1018-1021.

generated more power than the combined capacity of all other reclamation projects and netted \$486,000.¹²

While Reclamation Service officials and others recognized the many problems of national reclamation, they were reticent to recognize the tremendous potential of associating hydroelectrical production with reclamation development. In the May 1932 edition of The Reclamation Era, the Bureau's Chief Electrical Engineer, L. N. McClellan wrote, "Power development is becoming (emphasis added) one of the most important factors in the economic feasibility of Federal irrigation projects." While the Bureau was only beginning to apply the benefits of hydroelectricity in the 1930s, the Association had appreciably expanded its hydroelectric capacity in the 1910s with low-head hydro units and again in the 1920s under Cragin's hydroelectric expansion plan. Cragin and the Salt River Project recognized that hydroelectric production was an important, even necessary, element in irrigation development and that¹³ it could constitute another distinct part of reclamation.

The success of the Salt River Project's hydroelectric development became evident during the debate surrounding the passage of the Boulder Canyon Project Act in 1928. While the bill was under consideration, Arizona Senator Henry Ashurst testified, "When the United States Reclamation Service wants to refer to some project to justify its administration, to point to something successful that Federal bureaucracy can claim credit for, you will find that

¹²"Hydroelectric Power Development on the Projects," New Reclamation Era (June 1926) 1; U.S. Department of the Interior, Thirty-First Annual Report of the Commissioner of Reclamation (Washington D. C.: Government Printing Office, 1932):12-15.

¹³L. N. McClellan, "Power Development on Federal Reclamation Projects," The Reclamation Era 23 (May 1932): 90-91. Somewhat humorously and very inaccurately, The Reclamation Era in its July 1932 edition (page 121) subtitled the article, "Social and Economic Value of Electrical Development in Federal Reclamation," with the headline, "Reclamation Leads West in Introduction of Electricity." Although the Reclamation Service constructed the Association's low head Valley units in the 1910s it was the Association who argued for them and agreed to compensate the federal government for the additional construction expense. Organizationally the Association recognizes the dual function of reclamation. It employs water and power associate general managers.

the first project it refers to is the Salt River Valley project in Arizona." ¹⁴

The Boulder Canyon Project Act's officially stated purpose was to control floods, improve navigation, and regulate the flow of the Colorado River. However, the federal government knew that the states could not afford its estimated \$125 million construction cost without a added source of revenue. It knew that the project was not feasible without hydroelectric power. Because of this the Los Angeles Department of Water and Power and others paid for the project's hydroelectric units. Borrowing from the success demonstrated by the Salt River Valley Water Users' Association and smaller power producing reclamation and private projects, Congress also authorized the Boulder Canyon project for hydroelectric generation. It became the first federal multipurpose reclamation project. Indeed it was; however, its formula for success had been already proved in the Salt River Valley. Cragin and the Association understood that the power of falling water presented enormous economic opportunities. Hydroelectricity no longer was viewed as an incidental by-product of water storage but as a resource that could be developed singularly because it could be justified on its own merits. Through the Boulder Canyon Act the federal government ultimately recognized what the Salt River Project had shown, that hydroelectrical production in conjunction with water resource development provided fuller economic development of the West.

¹⁴U.S. Congress, Senate, Boulder Canyon Reclamation Project, Rept. 654, Part 2, 69th Cong., 1st. Sess., April 26, 1926.

Chapter Seven: Epilogue: Expansion Backlash, "Water Users Oust Cragin"

The Salt River Project is in 1988 a major electrical power producer in Arizona with assets exceeding \$5 billion. The Project has grown to become a major electrical producer over the last eighty-five years because it identified early in its history the importance of power production. The man most responsible for realizing this and developing the Association's power system was Charles C. Cragin. While Frank Reid's contributions were noteworthy, and later and much larger additions to the Association's power system dwarf Cragin's work, he established the Association as a major electrical utility and committed the organization to that end.

Despite his accomplishments, in May 1933, just three years after his hydroelectric expansion plan was completed, the Association Board of Governors, in their first meeting of 1933-1934, dismissed Cragin as General Superintendent and Chief Engineer. On May 1 the Board voted to replace Cragin with Association Power Superintendent Harry Lawson. Not only did the Board remove Cragin, but it replaced his entire staff: Legal Advisor John L. Gust; Assistant General Superintendent J. S. Connell; Assistant Treasurer P. V. Fuller; and Assistant Secretary and Paymaster Perry L. Simpson. Association Secretary Fred C. Henshaw did not accept reinstatement after learning that his salary was cut by eighteen percent. The removal of Cragin and other Association officers shocked the Board minority members and was greeted with equal amazement by the local newspapers. The lead headline in the Arizona Republic on May 2 read, "Water Users Oust Cragin." The article called the move the "greatest upheaval in the association's history." That same day the Phoenix Gazette called the Board's action a "startling upheaval" and "the most sweeping shake-up in the history of the organization."¹

While the Board's action may have appeared completely unexpected, considering Cragin's successful completion of the Association's hydroelectric expansion program, it was not. Beginning in 1925 a small group of shareholders began criticizing the Association's rapid expansion into the electrical utility business. Over the years this minority persisted in expressing disapproval. Their dissatisfaction with the expansion program and its costs had little effect initially, but by 1933 they had caused sufficient agitation

¹"Water Users Oust Cragin, Several Officers Removed," Arizona Republic, May 2, 1933, 1, 4; "Cragin Loses Post by Vote of Governors," Phoenix Gazette, May 2, 1933, pg?.

and won enough support to fire Cragin and his entire administration.

In the early stages of the hydroelectric expansion, Association shareholders widely supported the development plan. The Mormon Flat bond issue passed by a margin of fourteen to one. In his annual presidential report in May 1924, Reid recognized the popularity of the program when he spoke of the "sweeping endorsement of the organization and its policies." He referred to "a harmonious Board of Governors and Council," and of "individual members of the Association solidly back of this organization and its policies." He stated that the "record of the organization" had been "perfected." A year later, however, consensus began to disintegrate and the undercurrent of dissent was born.²

Objections to Cragin's program began in the spring of 1925. "Certain citizens," Reid stated in his annual report to the Board and Council, did not agree with the terms of the CALAPCO contract to construct the Mormon Flat power plant. Their protest was significant enough for Reid to answer it in his report. Objection arose, Reid stated, because some believed that the Association's hydroelectric power should be sold directly to Phoenix industries "for the benefit of the whole community."

Reid replied to his critics by first telling the Board that objections ought to be expected. He stated, "as the power business becomes more profitable, many people will desire to tell you how to run it for the benefit of other[s] than the farmers who own it." Reid justified the CALAPCO agreement in two ways. "The present law," he stated, "does not permit" power companies to earn more than ten percent profit on their investment. Reid estimated that the Mormon Flat power plant would net better than fifty percent. Why then, Reid asked, should the Association willingly reduce its net

²F. A. Reid, "Annual Report to Board of Governors and Council, Salt River Valley Water Users' Association," May 5, 1924, 1. File, "President's Report," Box E-2-15, Salt River Project Records Management.

³Frank Reid, "Annual Report to Board of Governors and Council, Salt River Valley Water Users' Association," August 3, 1925, 1-9. File, "President's Report." The report was reprinted in the Associated Arizona Producer 5 (August 15, 1926)" 4-5. The public versus private power debate was a national issue in the 1920s. It was a domestic topic during the 1924 presidential election, particularly for Progressive candidate Robert M. LaFollette.

revenues particularly when "the greatest industry Phoenix may ever posses [sic] is our project." "When the farmer is allowed to become prosperous," Reid said, "land values and the farming market improve." Greater land values and agricultural production would best serve the citizens and taxpayers of Phoenix. The "city's interests," he said, "[are] benefitted infinitely more [from Association prosperity] than with a few industries aided at the expense of the farmer." Secondly, Reid argued that the power business should naturally be a private monopoly to prevent duplication of investment and higher electrical rates. If the City of Phoenix, therefore, "does not desire private monopoly" he said, then it is "up to them to create a public monopoly." They should, he stated further, "not even suggest that the farmers should take on the job for less profit [or equal profit] than the local company can afford to distribute power for."⁴

In 1926 Reid again felt forced to defend Cragin's expansion plan. This time he responded to what he called "malicious misstatements made against the affairs of the Association" during the 1926 election and the "vicious attack" made on the 1924 Inspiration Copper contract to construct Horse Mesa. Reid explained that the kilowatt hour rate received under both the Inspiration and CALAPCO contracts, \$.0065 and \$.0085 respectively, were twice what comparable hydroelectrical plants in California and Colorado were receiving. The revenue from these contracts would, Reid said, reduce assessments or abolish them completely. "To put another way" Reid concluded, "The Inspiration contract is recognized by all sound-thinking business men familiar with it as the greatest guarantee to the credit of the Salt River Project."

Despite Reid's strident defense of his policies, criticism of the Association's management not only persisted but increased. In September 1926 Victor Steinerger, representing a group of 149 shareholders calling themselves the "Committee of Petitioners" solicited Secretary of the

⁴Ibid. Even though it was a government project, Reid was referring to the Salt River Project as a "private monopoly."

⁵Frank Reid, "Annual Report of President to the Board of Governors and Council of the Salt River Valley Water Users' Association," May 3, 1926, 1-11, File, "President's Reports."

Interior Herbert Work to investigate the Association's operations.

The Committee of Petitioners complained that Reid and Cragin were negligent in handling the finances of the Association. Steinerger stated that for the past two years Reid had accumulated excess charges equalling \$1.084 million and had not given a clear explanation of why these expenses existed. The petitioners knew that the Association was earning enough income through power receipts and acreage assessments to cover its costs. Why then did this deficit exist? Steinerger could only conclude that since assessments were being met and the estimated power income did not fall below projections, they must arise from excessive construction charges. Additionally, Steinerger and the committee were bothered by Reid securing from the Board the authority to borrow, at his discretion, \$1.451 million from the Valley Bank of Phoenix. Steinerger argued that this was in violation of the Association's Articles of Incorporation. For these reasons, the committee asked the government to make an investigation of the Association.

Almost immediately after the Committee of Petitioners submitted their complaint, the Board passed a resolution in September 1926 inviting the Secretary to investigate the affairs of the Association. Work ordered the investigation but not until February 1927. By that time relations between

⁶Victor Steinerger to Herbert Work, September 7, 1926, 1-8, Record Group 115, General Administrative and Project Records, National Archives, Washington D. C. Copy of letter available at the Salt River Project Research Archives.

⁷Ibid. "Water Users Must Show Publicity Demanded is Your Farm Their Security?" Five Points Star, August 4, 1926, 1. Record Group 115, General Administrative and Project Records, National Archives, Washington D. C. Copy of article available at the Salt River Project Research Archives. See also Victor Steinerger to Hubert Work, February 23, 1928, 1-6, Record Group 115, General Administrative and Project Records, National Archives, Washington D. C. Copy of letter available at Salt River Project Research Archives. What irritated Steinerger also was the increase in acreage assessments over three succeeding years. In 1924-1925 the assessment was \$2.00, in 1925-1926 it was \$3.00, and in 1926-1927 it was \$3.96. Section eight of Article 13 of the Association's Articles of Incorporation stated that no money in excess of \$100,000 could be borrowed for reasons other than ordinary operation and maintenance without majority approval of the shareholders.

Steinerger's group and Reid had deteriorated further. Steinerger was angered because he could not obtain a copy of the audited fiscal statement for 1925-1926 from the Association. He was also disturbed because Reid and Cragin had made it appear in the press that the Association requested the investigation. On February 27, the Arizona Republican reported the announcement of the investigation with the headline, "Water User Probe Here is Ordered, Secretary Work to Investigate Association Affairs at Request of General Superintendent." Steinerger complained that Cragin questioned the "motives" of the petitioners request. In a letter Cragin wrote on February 8, he stated that the "continued public propaganda" being disseminated concerning the Association's management was "undoubtedly" the result of "personal financial troubles." It was, he said, a "matter which will adjust itself with the breaking of the drought and better farm prices."

Secretary Work appointed H. T. Cory, a consulting engineer, to perform the investigation. W. A. Meyer, auditor for the Bureau of Reclamation assisted Cory in collecting financial and operational data. Cory arrived in Phoenix in July 1927 and immediately set to work. After spending two months questioning over one hundred individuals and reviewing the collected data with his brother, Dr. C. L. Cory, Professor of Electrical Engineering at the University of California, Cory reported his findings on October 4.

In a lengthy analysis, Cory addressed nine general propositions or criticisms which had been levied against the Association. Of the allegations concerning the hydroexpansion development (there were others that concerned the water system), Cory agreed most with the petitioners' contention that Reid and Cragin had entered into "ill-advised" power contracts. Cory concluded that "the outstanding contracts for hydroelectric power necessitates the conclusion that there has been general ignorance or disregard of present day public utility practice." This was

⁸Victor Steinerger to Hubert Work, March 24, 1927, 1-3, with attachments including, "Water Users Probe Here is Ordered," Arizona Republic, 1; C. C. Cragin to Hubert Work, February 8, 1927, 1-8, Record Group 115, General Administrative and Project Records, National Archives, Washington, D. C. Copy of letter is available at the Salt River Project Research Archives.

⁹H. T. Cory, "Report of Investigations in the Salt River Valley Project, Arizona," October 4, 1927. Reprinted in full in The Associated Arizona Producer 6 (November 1, 1927): 9-16.

because the Association was discriminating in service between consumers of like classes and had taken into consideration only "immediate financial interests" in formulating their development plan. Contracts were made for large blocks of power with preference over subsequent users in times of shortage and power rates differed depending on the particular unit and with varying degrees of service. The result of the long-term contracts did not produce, Cory said, "what all public utility commissions are striving to obtain, namely, uniformity of contract forms, service, rates and financing, with avoidance of long term contracts₁₀ in the interest of both the consumers and the utilities."

Concerning Reid's authority to secure a bank loan from Valley Bank and his acceptance of a \$400,000 advance from CALAPCO for hydroelectric equipment, Cory concluded that "if not the exact wording of the Articles of Incorporation call for approval by the stockholders of creating such obligations and probably it would have been better, entirely aside from legal consideration, if the management had secured such approval." As for the additional \$576,000 expense in the construction of Horse Mesa Dam, Cory did not see the petitioners' criticism as very substantive since "it is probably more the rule than exception that₁₁ large constructions exceed their estimated costs."

Steinerger and the committee also complained that Reid had proceeded with the hydroelectric program too fast. Cory emphatically disagreed. In fact he said the Association's management had proceeded too slowly. He recommended that it "immediately build Stewart Mountain dam and power plant" to enable the project to "serve the growing power demand of the area." Though they may have been slow, Cory thought Reid and Cragin were nonetheless "aggressive." Cory complimented the Association's management for "its record in getting things done." "There can be no question," he wrote, "but that it has 'gotten action' and has been exceptionally aggressive in the matter of constructions. In comparison with the usual shilly-shallying, vacillating and timorous

¹⁰Ibid., 10. Cory addressed other questions which did not deal with the hydroelectric program. These concerned the management of the water supply and delivery, assessments and charges for water delivery, maintenance of the canal distribution system, and agreements with Association landowners.

¹¹Ibid., 13-14.

managements, all too common in irrigation enterprises, that of this Project stands out boldly." ¹²

Finally, the petitioners complained that Reid held a lock on controlling the members of the Board and Council because he held 100,000 votes in "his hip pocket." Cory did not affirm the petitioners' belief but he did not deny their charge that a small group of large landholders, banks, and non-resident landholders controlled the Association's administration. Cory answered this complaint indirectly by suggesting that the 160 acre limitation be abolished because it was ineffective and counterproductive. "Irrigation farming," he said, "is not a poor man's game." ¹³

The report's conclusions neither justified all the claims of the petitioners nor condoned every action taken by Reid and Cragin. The final assessment was mixed. Cory stated that the "petitioners have many fanciful and, or unjustified grievances and a few legitimate complaints." The management of the Association, he stated, did not treat the power side, in reality, as a public utility because its sales agreements were not "in accord with standard public utility practice." Regardless, its actions, he believed, were "resulting in an unusually large net income." Reid and Cragin, he determined, were "more successful in [their] handling of the hydroelectric than of the irrigation features of the Project." Finally, he was critical of the Association for not making its annual 1926-1927 installment even though it collected assessments for that purpose. As for the petitioner's heavily implied hope that the federal government might take action, Cory disagreed. He recommended that the U.S. limit its relation with the Association to one of buyer and seller, only insisting that the Association make prompt payments to the government when its installments came due. ¹⁴

¹²Ibid., 12, 15. Comparing the Association to "common irrigation enterprises" was perhaps unfair since, as Cory admitted, Reid and Cragin placed most of their interests in the power side of the Association.

¹³Ibid., 10.

¹⁴Ibid., 16. Concerning the Association and federal government's relationship, Cory wrote it should be "limited to those usually existing between a seller and a buyer on the installment plan, and consequently is limited to the maintenance of unimpaired security and the prompt meeting of obligations, when and as due."

Cory did not write what he really thought of the Association in his investigation report. He made his true opinion known in a three page letter written to Reclamation Commissioner Mead the same day he released his report. In this correspondence, Cory stated that the Association "has been administered almost exclusively by two men," namely Reid and Cragin. He admitted this had advantages which he listed as, "continuity of policy," ability to "get things done," and the "rapid carrying out of constructive programs." However, it had an outweighing disadvantage, principally Reid and Cragin's "loss" of "their sense of proportion." In Cory's opinion the men had become "demagogues." Characterizing Reid, Cory said, "President F. A. Reid has many admirable qualities and falls just short of being a really big man." Concerning Cragin, Cory stated that he "is a good, high-powered, driving construction man." "Unfortunately," Cory concluded,

both of them came into power on this Project practically innocent of either public utility or irrigation experience. As the years have gone by, they have become somewhat unduly impressed with the importance of the hydroelectric side of the enterprise, which has had very much more interest and appeal for them than the rather drab, slow and painstaking evolution of the irrigation and agricultural features."¹⁵

Cory suggested that the actions of Reid and Cragin needed to be controlled but not immediately, or at least not until Reid "outlives his usefulness." "The inevitable finish of a man like President Reid," Cory wrote, "aggressive, militant, and disdainful of conciliatory methods, is the gradual piling up of personal animosities" which will lead to his "forcible elimination." But, "my own feeling, he stated, "is that until the Stewart Mountain dam and power plant, and electrical distribution system spread overall the Valley, and the badly needed additional pumping plants shall have been constructed, President Reid's continuance in control would be distinctly for the best interests of the Project." A change before the work was completed would lead to further demagoguery, he thought, and amount to little more than "changing the devil for a witch."

¹⁵H. T. Cory to Elwood Mead, October 4, 1927, 1-2, Record Group 115, General Administrative and Project Records, National Archives, Washington D. C. Copy of letter available at the Salt River Project Research Archives.

Cory advised the government use "strong arm methods" to contain Reid until Stewart Mountain was finished. One method which he was convinced would work would be the publishing of his report. As written, Cory believed that the report would have a "weakening" effect on Reid's control and would therefore diminish it. The result, he said, would be "letting the bars down against demagogu[e] [sic]." Additionally, Cory suggested that an agriculturist be "tactfully" brought into the project to lend authority and prestige to the Association's irrigation enterprise.¹⁶

The Cory report was published in full in The Associated Arizona Producer in November. Every shareholder, therefore, was provided with a copy of the investigation. The report did make an impact, but almost the opposite of what Cory desired and predicted. Cory thought Stewart Mountain Dam should be completed immediately and that Reid should not be removed until that was accomplished. Further, he also believed his report would diminish Reid's authority. Unfortunately, Cory did not realize that these goals were mutually exclusive. Stewart Mountain could not be built if Reid's power was effectively undermined.¹⁷

In March 1928 the Association held an election to approve the bonds to construct Stewart Mountain Dam. The vote failed to provide the required three to one ratio necessary to authorize the issue. The Producer claimed in its April 1 issue that many shareholders were "so absolutely confident" that the proposition would carry that they neglected to turn out and vote. At best, this explanation was only partially true. The Producer admitted in its June 1 issue that a "little group of professional agitators," had "succeeded in preventing the polling of the necessary 3 to 1 vote in favor of the bonds at the March election."¹⁸

¹⁶Ibid., 1-3.

¹⁷See note 10.

¹⁸"Confidence of Success Causes Loss of Stewart Mountain Election," The Associated Arizona Producer 4 (April 1, 1928): 4; Victor Steinerger to Hubert Work, February 23, 1928. The Committee of Petitioners did not believe that Stewart Mountain Dam was necessary to electrify the Valley. "The Motive Behind the Lawsuits Brought to Prevent the Stewart Mountain Development?" The Associated Arizona Producer 4 (June 1, 1928): 4. After the bonds were approved the "agitators" challenged the bond issue on legal grounds. The legal complaint was dismissed.

Obviously Cory's report did undermine the shareholders' confidence in the Reid and Cragin administration. The bond election passed after a second vote was taken but only barely and after twenty-five public meetings were held to sell the construction project. On May 8 the shareholders approved the issue by a five to one majority. Compared to the fourteen and twenty to one margins for Mormon Flat and Horse Mesa, the Stewart Mountain bonds achieved marginal approval.

Reid resigned immediately in 1930 after the completion of the Stewart Mountain Dam and power plant, and the electrification and drainage programs. He was not "forcibly eliminated" as Cory predicted but stepped down freely. Consistent criticism against his administration, leveled by a small but very vocal minority, undoubtedly took its toll on Reid and likely contributed to his departure. Cory's findings also helped. It was true, however, that Reid could credibly insist, as he did, that he had accomplished all his goals after five terms and ten years in office. He was a man who sought challenge and diversity. This was true of him before he joined the Association and after he left it. He may have been a man "disdainful of conciliation" as Cory characterized, but he knew that he had accomplished what he and Cragin set out to do in 1920. For him it was time to move on.

With Reid gone it was unlikely that Cragin would remain as General Superintendent and Chief Engineer. Only as a team did Reid and Cragin control the Association's management. Neither could have done it alone. Reid provided the political wisdom and savvy and Cragin the technological or engineering knowledge, skills that are frequently not natural partners. Without Reid to control the Association Board, Cragin's position became highly tenuous.

When the Board replaced Cragin on May 1, 1933 they did so by a narrow margin of six to five votes. The spring election of Board members had finally given Reid's opponents the numbers to oust his General Superintendent. The complaints against Cragin had been little different than those made against Reid. The Association policy of building dams and expanding its power system was still criticized, particularly because drought and the downturn in the copper industry made the Association's electrical business less profitable than had been predicted. Additionally, Cragin was personally attacked for his high salary, which had been \$20,000 annually before it was cut to \$12,500 because of the Depression. Not wasting any time, the new majority

struck. 19

Association President George W. Mickle began the May 1 Board meeting by proposing that the members reappoint their legal advisor John L. Gust. At that point newly-elected member Rudolph Johnson proposed a resolution that covered all appointments for the coming year. Johnson read a motion which replaced all current officers. It was immediately seconded by John Dobson, the man who had replaced Reid as president. Since the resolution was completely unexpected and unprecedented - Association posts were generally approved one at a time - President Mickle and members James Minotto and Obed Lassen pleaded to delay the vote. They wanted to avoid, what Minotto called "impulsive action." Mickle also asked Johnson whether those he listed as replacements were aware that their names were being submitted, particularly because C. W. Lillywhite, named to become Assistant General Superintendent, was residing in California. After Johnson admitted that he had not spoken to all those he named, a vote was taken to defer Johnson's motion. It fell short by the same six to five vote. Johnson, Dobson, T. T. Forman, Hollis Gray, James Wagoner, and R. K. Wood voted to remove Cragin and his staff. Mickle, Minotto, Lassen, Clyde Neely, and H. H. Wasser voted against. 20

The new majority acted quickly because two seats on the Board were being contested. On the face of the election, Clyde Neely was reelected over M. T. Schultz and Victor Corbell defeated Hollis Gray. However, it was contended by Gray and Schultz that in both elections acres were transferred from corporations to individuals so that the vote could be manipulated. If Gray and Schultz were seated, the vote would go seven to four against Cragin. If Neely and Corbell were seated, Cragin would win out six to five. 21

¹⁹"Council Threatens to Take Reins of Water Users, Overrule Governors, Re-employ Discharged Officials," Dunbar's Weekly 20 (May 5, 1933): 1, 6.

²⁰Ibid.; "Water Users Oust Cragin," Arizona Republic, May 2, 1933. Johnson answered Mickle's question concerning Lillywhite and the other individuals named as new officers by stating that, "they are entitled to accept or reject the offers."

²¹"Council Threatens to Take Reins of Water Users, Overrule Governors, Re-employ Discharged Officials," 6; "Cragin and Mickle Have Edge at the Moment in Battle to
(Footnote Continued)

Coincident to contesting the board seating was the Association Council's response to the Board's actions. The Association Council, consisting of thirty members, serves as the law-making arm of the Association and meets quarterly to ratify contracts, call elections, and change by-laws. The Council was controlled by the Mickle or pro-Cragin sympathizers. On Tuesday, May 2, Council Chairman H. C. Armstrong and Council Clerk H. W. Houston called a meeting for Saturday May 6 "for the purpose of revising the by-laws relating to officers and salaries, abolishing offices, creating offices and reducing and fixing salaries."²²

Before the Council met, on Wednesday May 3, Lawson dismissed I. M. Clausen, the last member of Cragin's staff. Clausen had served as Superintendent of Irrigation since Cragin appointed him in 1920. Lawson defended his termination of Clausen when the Board convened again on Thursday, May 4. In a meeting that brought "verbal clashes, hand clapping and 'boos'," according to the Phoenix Gazette, Board Governor Minotto attacked Lawson's action because it was conducted without the Board's vote. Minotto was angered because he learned of the dismissal through the newspapers and because "the management of the association" should not be "out of the hands of the board and the president." If "I am nothing but a rubber stamp here," he said, "I am going to protest." Lawson defended himself by asserting that his dismissal of Clausen was in keeping with the reorganization started by the Board two days previous. The change was for the purpose of harmony and "without harmony," Lawson said,²³ "the general superintendent cannot carry out his program."

While the Board would not meet again until May 15, great anticipation preceded the Council's May 6 session. Valley newspapers predicted that "Water Users Face New Row Over Cragin," and "Water Users Ousters May be Nullified." When²⁴ the Council met, the papers predictions proved accurate.

(Footnote Continued)

Control Affairs of Water Users' Association," Dunbar's Weekly 20 (May 12, 1933): 1, 6.

²²"Water Users' Council Moves to Attack Governors' Ouster of Five Executives," Arizona Republic, May 3, 1933, 1.

²³"Project Ousts I. M. Clausen," Arizona Republic, May 4, 1933, 4; "Boos and Cheers in Hall Stir Members," Phoenix Gazette, May 4, 1933, 1.

²⁴"Water Users Face New Row Over Cragin," Phoenix Gazette, May 5, 1933, 1; "Water Users Ousters May Be Nullified," Arizona Republic, May 6, 1933, 1.

In a meeting overseen by eight police officers and easily characterized as acrimonious, the Council not only struck down the Board's actions but passed several additional by-law amendments and resolutions which restructured the Association's management. The Council moved, by a generally consistent majority vote of twenty-one to eight, to appoint Cragin to a newly-created position of Project Manager, abolish the offices of Assistant General Superintendent and Assistant Secretary, set the salary of the General Superintendent and Chief Engineer at not to exceed \$1,000 per year, and prohibit the hiring or firing of an employee without the approval of the Board, President and Council. Several of the Council's actions passed over the objection of legal advice. ²⁵

After the Council reinstated Cragin, the Council minority, led by C. T. Thompson, petitioned the Maricopa County Superior Court to prohibit Cragin from assuming his previous duties with the Association. On Monday, May 8, Judge M. T. Phelps issued a restraining order enjoining Cragin from doing so. Phelps' order was only temporary; he scheduled a full hearing for May 15. ²⁶

More important to Cragin's fate than the Council's action and Phelps' injunction was whether Corbell and Neely, Cragin supporters, would be seated on the Board. When the Board met on May 15, Judge Phelps' temporary restraining order preventing the Board from declaring the results of the two contested elections had been dissolved by Judge Howard Spearman. Acting on Spearman's ruling, Mickle attempted to seat Corbell and Neely. However, he met immediate opposition from Dobson and Johnson. They asked that the ballots be canvassed. After several hours of argument the ballots were recounted. During the recount, Schultz produced several signed affidavits from shareholders who swore that they had voted and they did not own. Neely had no defense, or at least no affidavits of his own, so the

²⁵"Cragin Ouster Nullified, By-Laws Amended by Council," Arizona Republic, May 7, 1933 1, 5; "Give Cragin Job as Project Manager, New Post Created After Recent Ouster," Phoenix Gazette, May 6, 1933, 1, 3. The Council also passed actions to provide itself with approval authority for sales and rentals of Association property, and for Council authority to limit Board authority in making contracts.

²⁶"Cragin and Mickle Have Edge At the Moment in Battle to Control Affairs of Water Users' Association," 6; "Court Bars Cragin From Job, Usurping of Power Charged in Action," Phoenix Gazette, May 8, 1933, 1, 5.

recount went to Schultz. Dobson and his new majority declared Schultz the victor and he was seated. The Dobson faction also quickly voted to appoint a committee to investigate the Corbell-Gray contest. The men appointed to make the investigation, Wood, Johnson and Wasser, were all aligned with Dobson. ²⁷

When Schultz was seated the Board fight was over. Dobson had his six vote majority: himself, Johnson, Forman, Wood, Wagoner, and now Schultz. Mickle only had Lassen, Wasser, Minotto, and Corbell, if Gray did not replace him. When the Dobson majority picked its own men to investigate the Corbell and Gray election, the outcome was obvious. Gray was seated. The Dobson faction added another vote, which made a seven to four majority in Dobson's favor. ²⁸

For Cragin, the seating of Schultz ended his career with the Association. Even if the courts were to uphold the Council's action to appoint him project manager, he would likely be removed immediately by the Board. Certainly the Council might object again but this would result in more court action serving neither group's interests. ²⁹

The County Superior Court did not uphold Cragin's appointment as Project Manager. In a decision rendered by Judge P. A. Sawyer on June 26, 1933, the court ruled that the Council had acted "ultra vires" or beyond the scope of its powers as defined by the Association's Articles of Incorporation. For Cragin, however, the court's ruling was only academic. He could not return without the Board's

²⁷"Dobson Faction Gains Ally in Water Users as Schultz is Seated," Arizona Republic, May 16, 1923, 1, 4. Schultz produced affidavits claiming that 423 acres or votes were illegally cast. This changed the election result to 5,676 votes for Schultz and 5,564 for Neely.

²⁸"Dobson Faction Gains Ally in Water Users As Schultz is Seated," 4.

²⁹The Cragin hearing was postponed until the end of May and a change of venue was made in the case. It was heard by Navajo County Superior Judge P. A. Sawyer from Holbrook, Arizona. According to the newspaper account, Judge Sawyer stated that he would deliver his ruling in the case by mail. "Cragin Ouster Case is Argued," Arizona Republic, June 2, 1933, 3, C-1.

support even if the court approved his appointment. With no options remaining, Cragin left the Association.³⁰

Soon after the events of May and June 1933, Cragin accepted a position as Vice President and Assistant General Manager of El Paso Natural Gas of El Paso, Texas. Cragin was hired by El Paso President Paul Kayser who knew Cragin's reputation as an experienced executive and engineer in the utility field. Kayser also knew that Cragin understood the attractive Arizona power market. Knowing Cragin's reputation as a tremendously driven construction man, Kayser concluded that with Cragin, El Paso's chances for success in Arizona were great.

Kayser's opinion of Cragin proved correct. Before the end of 1933 Cragin expanded El Paso's operations into Arizona completing a 217 mile pipeline from Texas to Tucson. Two months later El Paso's lines reached Phoenix. In 1935 Cragin was running a pipeline from Casa Grande, between Tucson and Phoenix, and to Superior to feed the Magma Copper Company. By the end of that year he had also expanded service into Coolidge and Florence, towns southeast of Phoenix, and into Ajo, southwest of the Valley. During World War II El Paso's growth slowed, due in part to the loss of employees to the military services. After the war Cragin and Kayser expanded again, this time into the phenomenally growing Southern California communities.

What Cragin did for the Water Users' Association he did for El Paso but in a much bigger way. When he retired from the natural gas company in 1953 at approximately the age of seventy, the twenty-five year old business had grown from a \$10 million company when Cragin joined it in 1933 to one worth \$1 billion.³¹

There is no doubt that Charles Calhoun Cragin was exceedingly driven, fervently devoted, strong willed, and visionary, perhaps to a fault. His talents led him to assess masterfully the potential of the Association (and El Paso) and develop it tirelessly. He saw the Water Users' Association, as his son George stated, as an organization

³⁰C. T. Thompson v. C. C. Cragin and Salt River Valley Water Users' Association, June 27, 1933, 1-4, Maricopa County Superior Court, Docket Number 39198-C.

³¹Correspondence with John H. McFall, Director, Public Relations, El Paso Natural Gas Company, August 1988; "New York University Honors C. C. Cragin," El Paso Herald Post, January 12, 1955, 1, 3. "Career of C. C. Cragin was Tops in Industry," El Paso Herald Post, October 8, 1962.

much greater than, "a group of farmers . . . worrying [only] about the water to their crop."³² Cragin saw an industry which could not only farm the entire Phoenix Valley but electrify it as well. Unfortunately, Cragin (and Reid) did not do enough to convince others of this and subsequently not everyone recognized his skill or understood his compulsion. Consequently, the Association thanklessly removed from office the man who transformed the Association enabling it to become a major municipal utility.

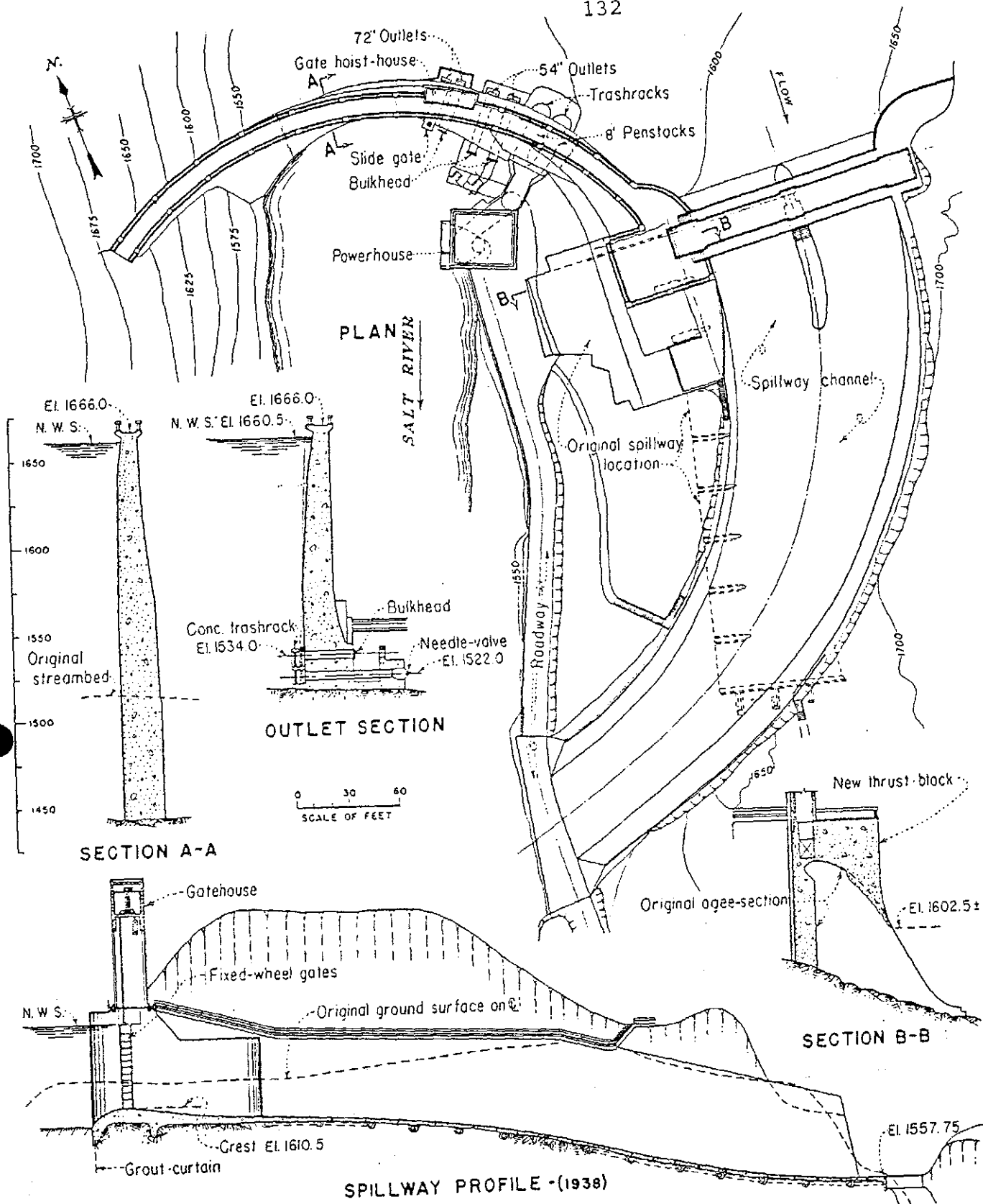
In 1962 Charles Cragin died in El Paso. His last wish was for his ashes to be dispersed over his favorite place, Mormon Flat Lake. This was a fitting conclusion to the man's life.

³² Interview with George Cragin, 1-42.

Appendix I
Chronology of Events
Association Hydroelectric Expansion Program

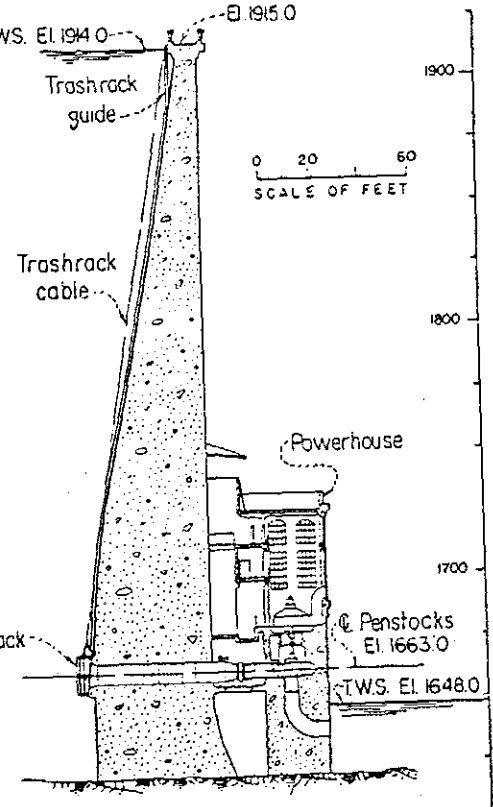
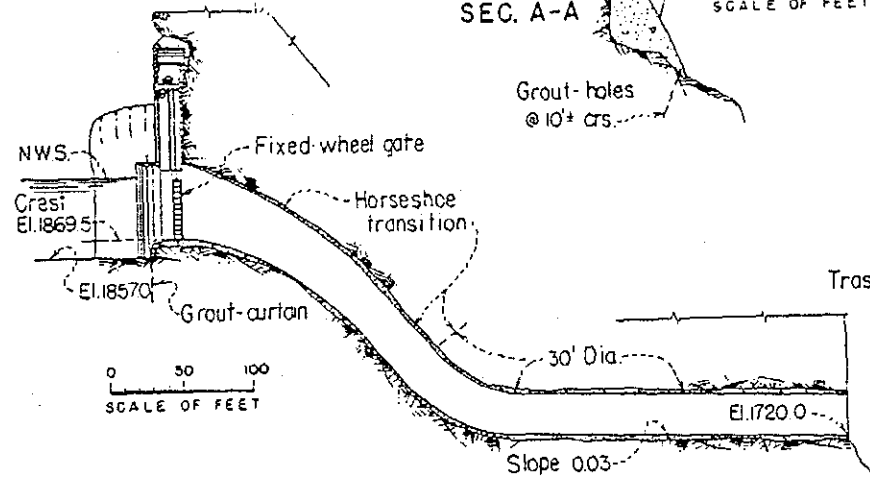
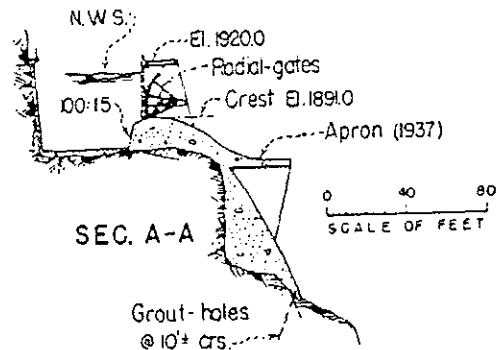
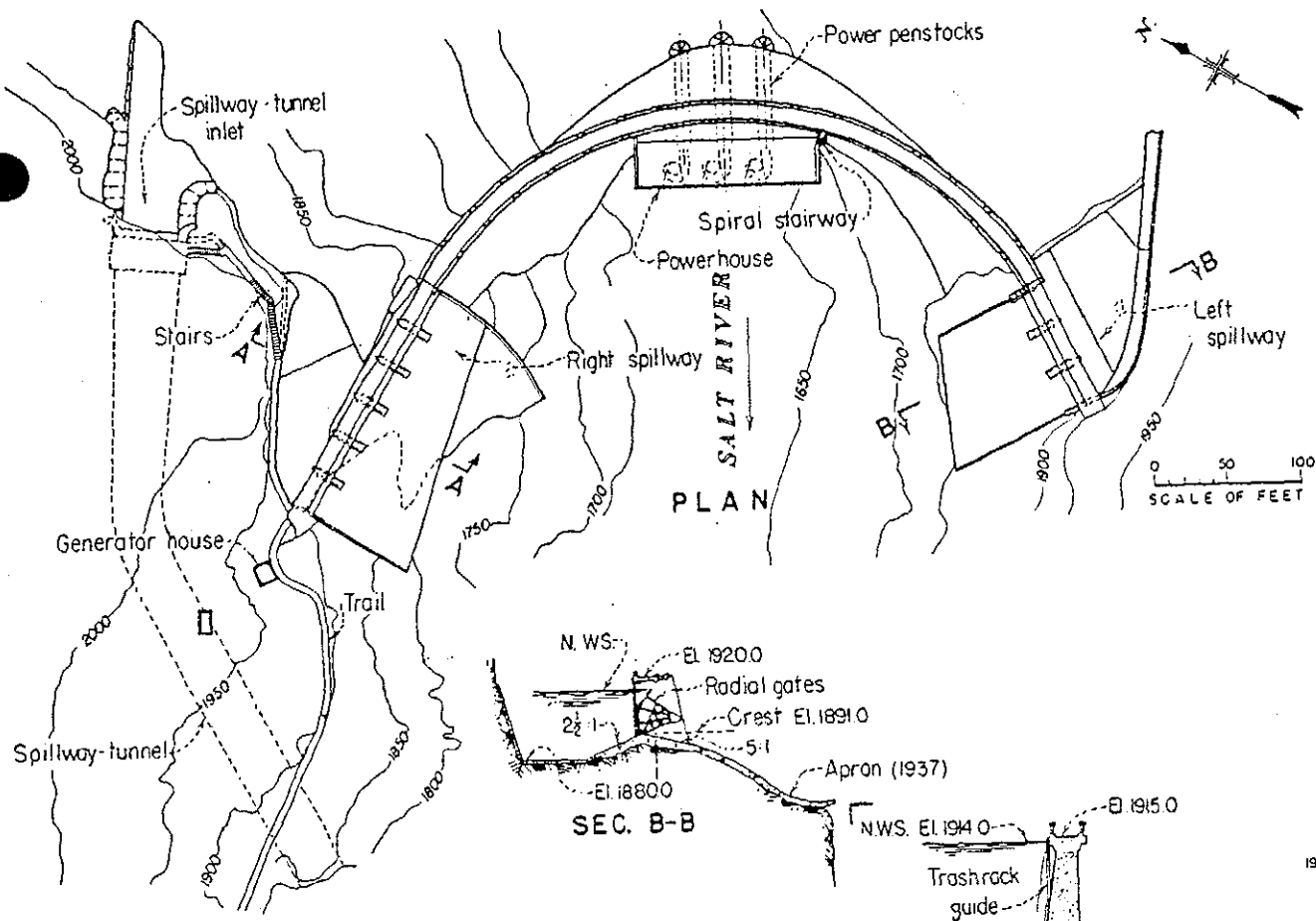
<u>DATE</u>	<u>EVENT</u>
February 1922	Cragin report issued.
July 1922	U.S. approves hydroelectric expansion program.
March 1923	Upgrades at Roosevelt Dam completed.
April 1923	Preliminary work at Mormon Flat begun.
March 1924	First concrete poured at Mormon Flat.
June 1924	Agreement with Inspiration for Horse Mesa power.
June 1924	Preliminary work at Horse Mesa begun.
April 1925	Mormon Flat Dam completed.
June 1925	Agreement with CALAPCO for Mormon Flat power.
May 1926	Mormon Flat Power Plant completed.
May 1926	First concrete poured at Horse Mesa.
April 1927	Horse Mesa Power Plant put in service.
October 1927	Horse Mesa Dam completed.
March 1930	Stewart Mountain Dam completed.

Appendix II
Mormon Flat Dam, Plan and Sections.
(Source: U.S. Department of the Interior.
Water and Power Resources Service,
Project Data, 1981.
Denver: Government Printing Office, 1981.)



Mormon Flat Dam, Plan and Sections

Appendix III
Horse Mesa Dam and Powerplant, Plan and Sections.
(Source: U.S. Department of the Interior.
Water and Power Resources Service,
Project Data, 1981.
Denver: Government Printing Office, 1981.)



Horse Mesa Dam and Powerplant, Plan and Sections

Appendix IV

A Comparison of Arch Dams

(Source: Figure 3-2 in, Kollgaard, Eric B.,
and Chadwick, Wallace L., Development of
Dam Engineering in the United States.

New York: Pergamon Press, 1988.)

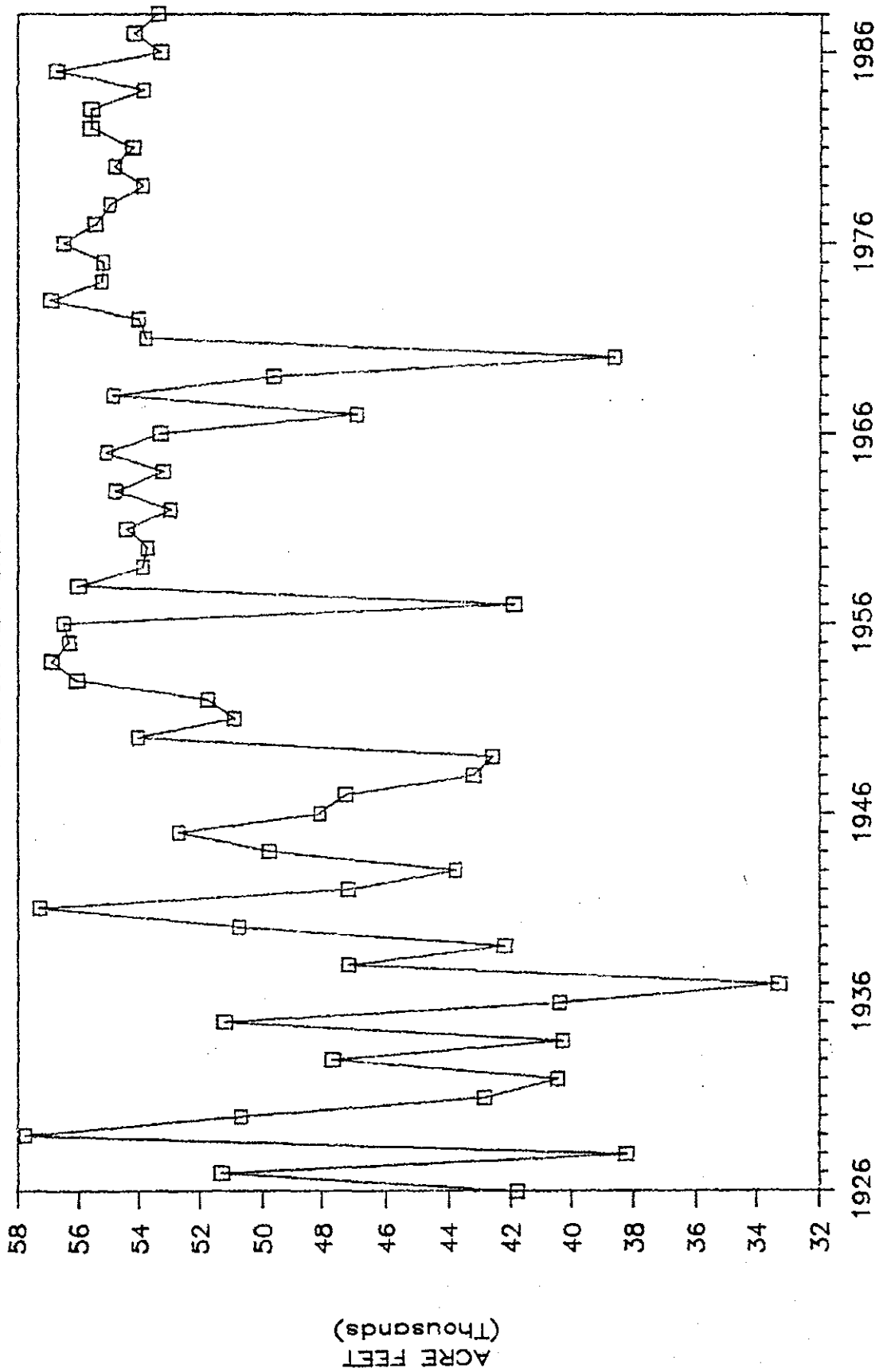
A Comparison of Arch Dams

	Date	Volume (cy)	Crest Length (ft)	Height (ft)	Thickness Base (ft)	Top (ft)
Bear Valley	1884	3,000	450	64	22	3
Sweetwater	1888	19,750	350	98	46	12
La Grange	1893	39,500	336	131	79.5	24
Upper Otay	1901	3,700	350	89	14	4
Lake Cheesman	1905	103,000	670	227	176	18
Pathfinder	1909	65,700	432	214	97	10.9
Buffalo Bill	1910	82,900	200	325	108	10
Roosevelt	1911	355,800	723	280	134	16
Salmon Creek	1914	54,000	648	170	47.5	6
Lake Spaulding	1919	189,300	800	276	94	11
Mormon Flat	1925	42,980	380	142	20	8
Stevenson Creek	1926	370	140	60	7.5	2
Horse Mesa	1927	150,000	660	305	43-57	8
Pacoima	1929	226,140	640	372	100	10.4
Gibson	1929	167,500	960	199	117	15
Owyhee	1932	537,500	833	417	265	30
Hover	1935	4,400,000	1,244	726	660	45
Parker	1938	390,000	856	320	100	39
Ross	1949	909,200	1,300	540	208	33
Hungry Horse	1953	3,086,200	2,115	564	330	39

Appendix V
Reservoir Storage
Mormon Flat Dam

RESERVOIR STORAGE

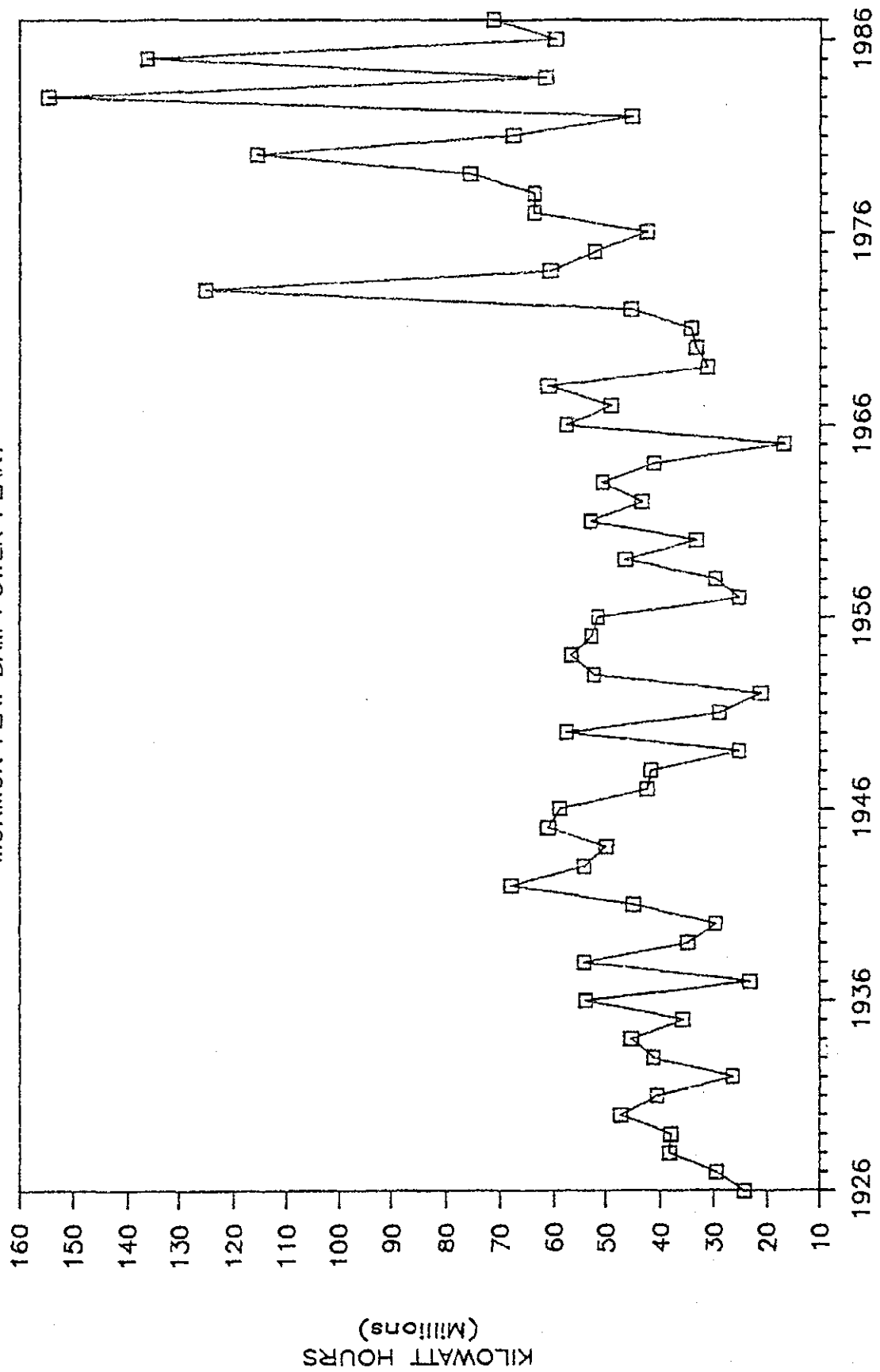
MORMON FLAT DAM



Appendix VI
Hydroelectric Power Generation
Mormon Flat Dam Power Plant

HYDROELECTRIC POWER GENERATION

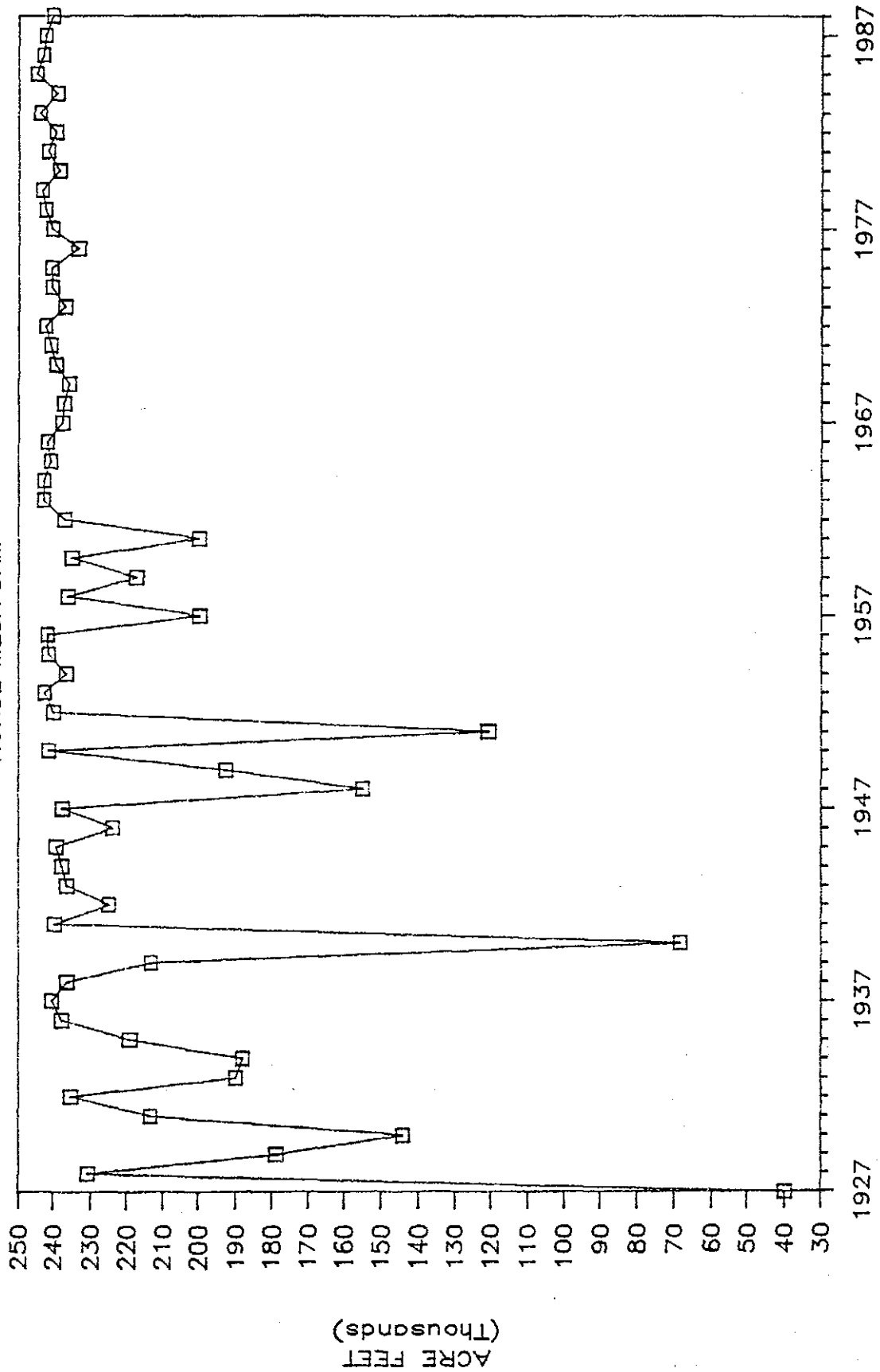
MORMON FLAT DAM POWER PLANT



Appendix VII
Reservoir Storage
Horse Mesa Dam

RESERVOIR STORAGE

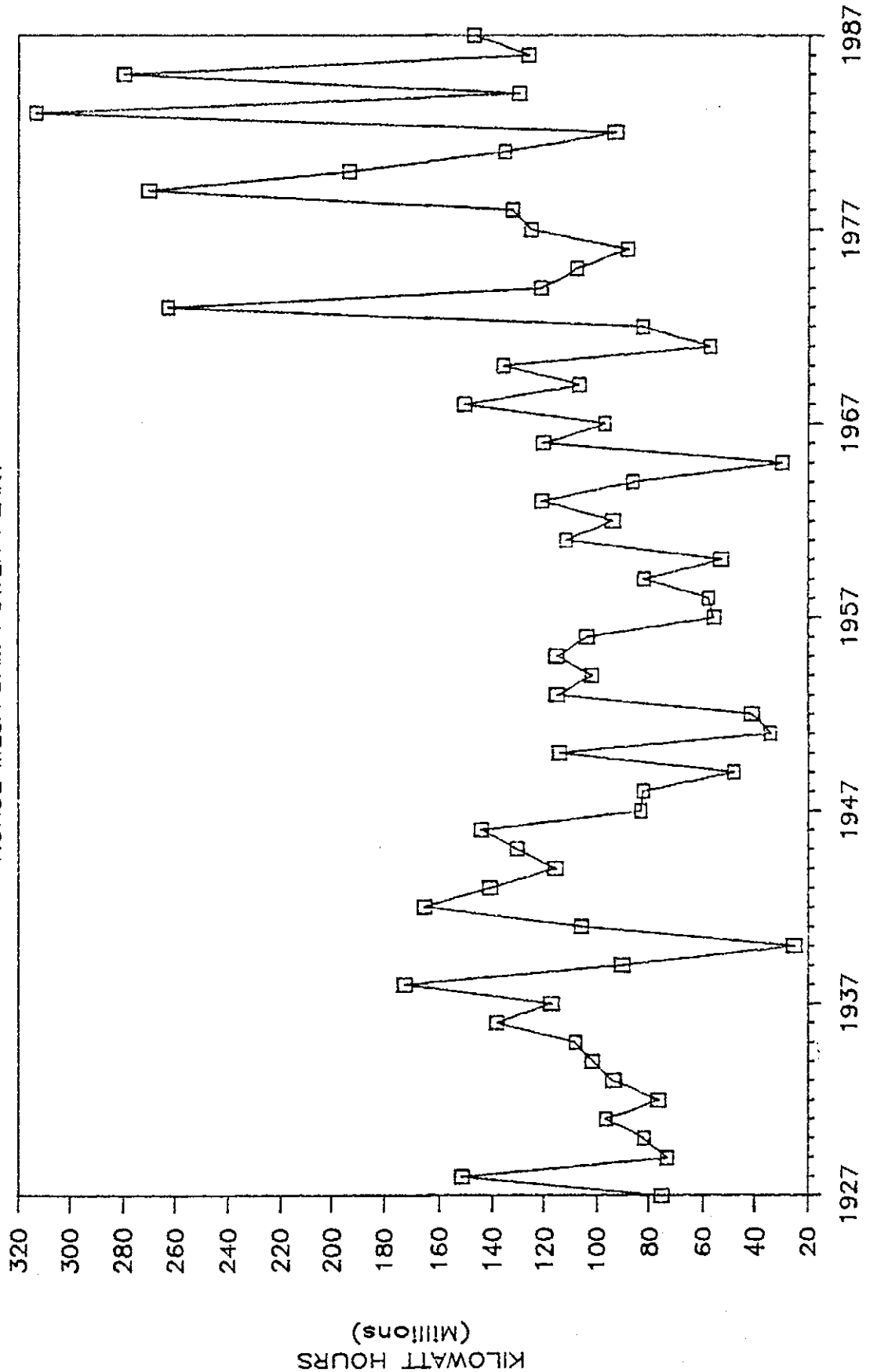
HORSE MESA DAM



Appendix VIII
Hydroelectric Power Generation
Horse Mesa Dam Power Plant

HYDROELECTRIC POWER GENERATION

HORSE MESA DAM POWER PLANT



Bibliography

I. Manuscript and Archival Collections

Arizona, Tempe, Arizona Historical Collection, Arizona State University.

_____. Arizona Historical Foundation, Arizona State University.

_____. Research Archives, Salt River Project.

_____. Records Management, Salt River Project.

_____. Secretary's Office, Salt River Project.

Arizona, Phoenix. Arizona Department of Water Resources.

_____. Arizona State Library and Archives.

_____. Arizona State Supreme Court.

_____. Maricopa County Recorder's Office.

_____. Maricopa County Superior Court.

_____. Phoenix Public Library, Arizona Room: James H. McClintock Collection.

Arizona, Tucson, University of Arizona, Special Collections.

California, San Francisco, Leedshill-Herkenhoff Engineering Firm.

Washington, D.C. National Archives and Records Administration. Record Group 115, U.S. Bureau of Reclamation.

II. United States Government Documents

U.S. Congress. House. Commission on Organization of the Executive Branch of the Government. Water Resources and Power. 84th Cong., 1st Sess., 1955. Doc. No. 208.

_____. Committee on Public Lands. Providing for Return of Rehabilitation and Betterment of Costs of Federal Reclamation Projects: to Accompany H.R. 1694. 81st Cong., 1st Sess., May 16, 1949. Rept. 589.

U.S. Congress. Senate. Report of the Special Committee of the United States Senate on the Irrigation and Reclamation of Arid Lands. 51st Cong., 1st Sess., 1890. Doc. No. 928.

_____. Boulder Canyon Reclamation Project. 69th Cong., 1st Sess., April 26, 1926, Rept. 654, Pt. 2.

U.S. Department of Interior. Geological Survey. Irrigation Near Phoenix, Arizona. By Arthur P. Davis. Water Supply and Irrigation Paper No. 2. Washington, D. C.: Government Printing Office, 1897.

_____. Power Capacity and Production in the United States. by C. R. Daugherty, A. H. Horton, and R. W. Davenport. Water Supply and Irrigation Paper 579. Washington, D. C.: Government Printing Office, 1928.

_____. "Reservoirs for Irrigation," in Eighteenth Annual Report of the United States Geological Survey, 1896-1897, Part IV Hydrography. Washington D. C.: Government Printing Office, 1897.

_____. Water Storage on Salt River, Arizona. By Arthur Powell Davis, Water Supply and Irrigation Paper No. 73. Washington D. C.: Government Printing Office, 1903.

_____. The Underground Waters of Gila Valley, Arizona. By Willis Thomas Lee, Water Supply and Irrigation Paper No. 104. Washington D. C.: Government Printing Office, 1904.

_____. Underground Waters of Salt River Valley, Arizona. By Willis Thomas Lee. Water Supply and Irrigation Paper No. 136. Washington, D.C.: Government Printing Office, 1905.

_____. Reclamation Service. Annual Reports of the U.S. Reclamation Service, 1902-1932.

_____. Annual History of the Salt River Project, 1911-1917.

_____. Salt River Project, Arizona, Final History to 1916. 3 Vols. April 1, 1916, (Typewritten.)

III. Newspapers

Arizona. Phoenix, The Arizona Democrat.

_____. The Associated Arizona Producer.

_____. The Arizona Gazette.

_____. The Arizona Republican.

_____. Dunbar's Weekly.

Texas, El Paso, El Paso Herald Post.

IV. Dissertations and Theses

Davison, Stanley Roland. "The Leadership of the Reclamation Movement, 1875-1902." Ph.D. dissertation, University of California, 1952.

Foster, Abram John. "The Coming of the Electrical Age to the United States." Ph.D. dissertation, University of Pittsburgh, 1952.

Henderson, Patrick, "The Public Domain in Arizona: 1863-1891." Ph.D. dissertation, University of New Mexico, 1965.

Hornig, Edgar Albert. "Reclamation of Arizona's Arid Lands." M.A. Thesis, University of Oklahoma, 1942.

Jackson, Donald C. "A History of Water in the American West: John S. Eastwood and 'The Ultimate Dam' (1908-1924)." Ph.D. dissertation, University of Pennsylvania, 1986.

Jewett, John Quincy. "Economic Analysis of the Hydro-Electric Power System of the Salt River Irrigation Project in Arizona." M.A. Thesis, University of Colorado, 1929.

Mawn, Geoffrey P. "Phoenix, Arizona: Central City of the Southwest, 1870-1920." Ph.D. dissertation, Arizona State University, 1979.

Ziemann, Jay C. "The Modernization of the Salt River Project; The Impact of the Rehabilitation and Betterment Program." M.A. Thesis, Arizona State University, 1987.

V. Articles and Other Papers

"Arch Dam of Thin Section Now in Service on Salt River," Engineering News-Record 96 (May 13, 1926): 778.

Bechtel Corporation. "Frequency Unification and Hydro Extension Study for Salt River Project." 1967. (Typewritten.)

"Bigger Spillways for Salt River Dams," Engineering News-Record 21 (August 11, 1938): 174-177.

Brandow, Glenn W. Historical Documents Pertaining to Power Contracts and Agreements of the Salt River Project. Phoenix: Salt River Project. (Typewritten.)

Brook, H. H. "Difficulties and Complaints of the Farmer." Engineering News-Record 91 (November 29, 1923): 890-892.

Bruere, Martha Bensley, "Following the Hydro." The Survey 51, (March 1, 1924): 591-594.

Bruere, Robert W. "Giant Power - Region-BUILDER." The Survey 51 (March 1, 1924): 161-164, 188.

_____. "Pandora's Box." The Survey 51 (March 1, 1924): 557-560.

Butler, H. G. "Pools of Power." The Survey 51 (March 1, 1924): 605-609.

Cabot, Philip. "National Electrical Highways." The Survey 51 (March 1, 1924): 581-583.

Comstock, Charles W. "The Future of Water Power in the United States." Paper presented to the American Institute of Electrical Engineers, Denver, Colorado, February 19, 1916.

Cone, William S. "Report on Inspection of Horse Mesa, Mormon Flat and Stewart Mountain Developments." July 21, 1933. (Typewritten.)

Connell, J. S. "Organization, Equipment and Methods, Building a Huge Irrigation and Power Project in Arizona," Contractors and Engineers Monthly 27 (August 1930): 55-60.

Cory, H. T. "Report of Investigations in the Salt River Valley Project, Arizona." October 4, 1927. (Typewritten.)

Cragin, Charles C. "Development of Hydro-Electric Power as an Aid to Irrigation," Proceedings of American Society of Civil Engineers 58 (April 1932): 545-557.

_____. "Horse Mesa Dam, Salt River Project, Arizona," New Reclamation Era 21 (September 1930): 174-176.

_____. "Mormon Flat Dam, Salt River Project, Arizona," New Reclamation Era 21 (June 1930): 110-112.

Cragin, Charles C.; O'Hara, Francis J.; and Lawson, Henry J. "Report on Proposed Additional Hydro-Electric Power Development of the Salt River," Phoenix: Salt River Project, February 1923. (Typewritten.)

Debler E. B. and Tebow, H. J. "Spillway Requirements, Salt River Project Dams." December 28, 1934. (Typewritten.)

Dibble, Barry. "Engineering and Economic Examination of Salt River Valley Water Users' Association, Salt River Project." January 1935. (Typewritten.)

Dickerman, Alan R., Radosevich, George E., and Nobe, Kenneth C. "Foundations of Federal Reclamation Policies: An Historical Review of Changing Goals and Objectives." 1969. (Typewritten.)

Dunn, Gano. "The Water Power Situation, Including its Financial Aspect." Paper presented to the American Institute of Electrical Engineers, Washington, D. C., April 26, 1916.

"The First Three-Phase Transmission Plant in the United States." The Electrical Review 34 (February 16, 1894): 171.

Fraps, J. A. "Construction of Alterations to Spillway, Roosevelt Dam, Salt River Project, Phoenix, Arizona." June 24, 1937. (Typewritten.)

Ganoe, John T. "The Beginnings of Irrigation in the United States." Mississippi Valley Historical Review 25 (June 1938): 59-78.

_____. "The Origin of a National Reclamation Policy." Mississippi Valley Historical Review 18 (June 1931): 34-52.

Gaylord, James M. "Power and Pumping System of the Salt River Project, Arizona. January 1, 1914. (Typewritten.)

Grunsky, C. E. "The Development of the West Under Irrigation." Engineering News-Record 91 (November 1, 1923): 715-718.

Hamlin, Homer. "Report Upon the Development and Distribution of the Water Resources of Salt River Valley, Arizona." January 21, 1920. (Typewritten.)

Hard, William. "Giant Negotiations for Giant Power." The Survey 51 (March 1, 1924): 577-580.

Hart, Joseph K. "Power and Culture." The Survey 51 (March 1, 1924): 625-628.

Hayden, T. A. "Salt River Project, Arizona, Irrigation and Hydroelectric Development by Salt River Valley Water Users' Association - Six Major Dams," Western Construction News 5 (June 25, 1930 and July 10, 1930): 293-302, 319-327.

Hill, Louis C. "Report, Inspiration Consolidated Copper Co.," June 27, 1922. (Typewritten.)

_____. "Economic Survey of Salt River Project, Arizona." September 1942. (Typewritten.)

Hinds, Julian. "Continuous Development of Dams Since 1850," Transactions of the American Society of Civil Engineers, CT (1953): 489-503.

Howell, C. H., and Jaquith, A. C. "Analysis of Arch Dams by the Trial Load Method." Proceedings of the American Society of Civil Engineers 54 (January 1928): 61-95.

Hughes, Thomas P. "The Industrial Revolution That Never Came." American Heritage of Invention and Technology 3 (Winter 1988): 59-64.

"Hydroelectric Power Development on the Projects," New Reclamation Era 17 (June 1926): 1.

"Increasing Spillway Capacities at Four Large Dams on the Salt River." Western Construction News 13 (November 1937): 453-456.

Introcaso, David M. "The History of Water Storage Development on the Agua Fria River: The Construction of Waddell Dam." National Park Service, Historic American Engineering Record Report, AZ-11, 1988.

_____. "The Roosevelt Power Canal and Diversion Dam." National Park Service, Historic American Engineering Record Report, AZ-4, 1984.

_____. "Water Development on the Gila River: The Construction of Coolidge Dam." National Park Service. Historic American Engineering Record Report, AZ-7, 1986.

"Irrigation In Arizona." The Irrigation Age 5 (July 1893): 55.

Jackson, Donald C. "John S. Eastwood and the Mountain Dell Dam." The Journal of the Society for Industrial Archaeology 5 (1979): 33-48.

Jakobsen, B. F. "Approximate Formulas for Arch Dam Design." Engineering and Contracting 67 (January 1928): 25-27.

_____. "Volume Relation of Constant Angle Arch Dams and Gravity Dams." Engineering and Contracting 54 (December 8, 1920): 554-557.

Jorgensen, Lars. "The Constant-Angle Arch Dam." Transactions of the American Society of Civil Engineers 78 (1915): 685-733.

_____. "Improving Arch Action in Arch Dams." Transactions of the American Society of Civil Engineers 83 (1919-1920): 316-336.

_____. "Memorandum on Arch Dam Developments." Proceedings of American Concrete Institute Convention 27 (1931): 1-64.

Koppen, E. C. "Construction of Alterations to Spillway, Roosevelt Dam, Salt River Project, Phoenix, Arizona." June 24, 1937. (Typewritten.)

_____. "Construction of Spillway Channel, Stewart Mountain Dam, Salt River Project, Phoenix, Arizona." February 2, 1937. (Typewritten.)

_____. "Building Bartlett Dam," The Reclamation Era 30 (November 1939): 308-314.

_____. "Department of Interior, Bureau of Reclamation, Salt River Project, Arizona, Project History, 1938." 1938. (Typewritten.)

_____. "Department of Interior, Bureau of Reclamation, Salt River Project, Arizona, Project History, 1937." 1937. (Typewritten.)

_____. "Department of Interior, Bureau of Reclamation, Salt River Project, Arizona, Project History, 1935-1936." 1936. (Typewritten.)

_____. "Final Report, Construction, Spillways for Horse Mesa Dam, Salt River Project." September 20, 1938. (Typewritten.)

_____. "Salt River Project, Horse Mesa Dam and Spillways," July 19, 1935. (Typewritten.)

Kreutzer, George C. "After Reclamation, Organized Land Settlement." Engineering News-Record 91 (November 22, 1923): 838-841.

Lambert, Larry K. "Mormon Flat Dam - Salt River Project, Phoenix, Arizona, U.S.A." Paper prepared for the United States Committee on Large Dams, October 30, 1986. (Typewritten.)

Larson, Richard T. "Interesting Construction at Horse Mesa Dam." The Reclamation Era 28 (June 1937): 132-135.

Layton, Edwin, "Mirror-Image Twins: The Communities of Science and Technology in 19th-Century America." Technology and Culture 12 (1971): 562-580.

_____. "Scientific Technology, 1845-1900: The Hydraulic Turbine and the Origins of American Industrial Research." Technology and Culture 20 (1979): 64-89.

Lilley, William and Gould, Lewis L. "The Western Irrigation Movement 1878-1902: A Reappraisal," in The American West, ed. by Gene M. Gressley. Laramie: University of Wyoming, 1966.

Mattison, Allen. "Spillway Reconstruction at Mormon Flat Dam," The Reclamation Era 29 (May 1938): 94-95.

McClatchie, Alfred J. Irrigation at the Station Farm, 1898-1901. Arizona Agriculture Experiment Station, 1902, Bulletin No. 41.

McClellan, L. N. "Power Development on Federal Reclamation Projects." The Reclamation Era 23 (May 1932): 90-91.

McConaughy, D. C. and Lieurance, R. S. "Report on Stewart Mountain Dam, Mormon Flat Dam, Horse Mesa Dam, Roosevelt Dam, Salt River Project, Arizona," February 1, 1935. (Typewritten.)

Means, Thomas H. "Faults of Reclamation Law and Practice, and Their Remedies." Engineering News-Record 91 (December 13, 1923): 977-981.

Morong, T. M., Lauerman, E. J., and Hollewell, J. A. "The Salt River Project's Hydro Expansion and Frequency Unification Program." Paper presented at the Institute of Electrical and Electronics Institute, Phoenix, Arizona, April 18, 1969.

Mumford, Lewis. "The Fourth Migration." The Survey 51 (March 1, 1924): 130-133.

_____. "Regions-To Live In." The Survey 51 (March 1, 1924): 151-152.

Myers, Cindy L. and Rogge, A. E. ed., "First Annual Report, Historical Archaeological Investigations at Dam Construction Camps in Central Arizona." Phoenix: Dames and Moore Engineering Firm, October 1987. (Typewritten.)

_____. "D-R-A-F-T, A Plan for Investigating Historic Dam Construction Camps in Central Arizona." Phoenix: Dames and Moore Engineering Firm, January 1987. (Typewritten.)

Newell, F. H. "Origin, Problems and Achievements of Federal Land Reclamation." Engineering News-Record 91 (October 25, 1923): 666-673.

_____. "Twenty Years of Reclamation." Engineering News-Record 91 (November 15, 1923): 801-807.

Peterson, W. H. "Cave Creek Flood Control Dam, Multiple Arch Structure Built Along New Lines." Southwest Builder and Contractor 62 (February 16, 1923): 30-33.

Pinchot, Gifford. "Giant Power." The Survey 51 (March 1, 1924): 561-562.

Pisani, Donald J. "Reclamation and Social Engineering in the Progressive Era." Agricultural History 57 (January 1983): 46-63.

Ransome, F. L. "Geological Report on Spillway Conditions at Mormon Flat and Horse Mesa Dams, Arizona," April 15, 1935. (Typewritten.)

Salt River Project, "Annual Histories," 1918-1948. Phoenix: Salt River Project.

Schad, Theodore M. and Rose, John Kerr. "Reclamation - Accomplishments and Contributions." Washington D. C.: Library of Congress, Legislative Reference Service, December 15, 1958.

Schofield, Carl S. "Agriculture on Irrigated Lands." Engineering News-Record 91 (November 8, 1923): 756-761.

Shaw, F. M. "Final Inspection of Salt River Spillways." The Reclamation Era 29 (August 1938): 172, 175.

Smith, Addison T. "The Future of Federal Reclamation." The Engineering News-Record 91 (December 20, 1923): 1018-1021.

Smith, Alfred E. "The Stake of the Public." The Survey 51 (March 1, 1924): 574-576.

Smith, Karen L. "The Campaign for Water in Central Arizona, 1890-1903." Arizona and the West 23 (Summer 1981): 127-148.

"Social and Economic Value of Electrical Development in Federal Reclamation." The Reclamation Era 23 (July 1932): 121.

Sterling, Everett. "The Powell Irrigation Survey, 1888-1983." Mississippi Valley Historical Review 27 (December, 1940): 421-434.

Stucky, Alfred, "Study of Arched Dams." Bulletin Technique de la Suisse Romande, 1922.

Swope, Gerard. "The Engineer's Place in Society." The Survey 51 (March 1, 1924): 635-636, 652.

Thon, J. George; O'Hara, John W.; and Whalin, C. H. "Modernization of Dams on the Salt River." Paper presented at the American Society of Civil Engineers, New Orleans, Louisiana, February 4, 1969.

Wells, Philip P. "Our Federal Power Policy." The Survey 51 (March 1, 1924): 569-573, 649.

Westergaard, H. M. "Arch Dam Analysis by Trial Loads Simplified," Engineering News-Record (January 22, 1931): 141-143.

Whitehead, James T. "Financial Troubles of the Reclamation Farmer and How They May Be Relieved." Engineering News-Record 91 (December 6, 1923): 924-925.

VI. Books

Barnes, Will C. Arizona Place Names. Revised and Enlarged by Byrd H. Granger. Tucson: The University of Arizona Press, 1960.

Billington, David P. The Tower and the Bridge, The New Art of Structural Engineering. New York: Basic Books, 1983.

Dunning, Charles H. Rock to Riches. Phoenix: Southwest Publishing Company, 1959.

Faulk, Odie B. Arizona, A Short History. Norman: University of Oklahoma Press, 1970.

Golze, Alfred R. Reclamation in the United States. Idaho: The Caxton Printers, 1961.

Gressley, Gene M., ed., The American West. Laramie: University of Wyoming, 1966.

Kollgaard, Eric B., and Chadwick Wallace L., eds., Development of Dam Engineering in the United States. New York: Pergamon Press, 1988.

Hamilton, Patrick. The Resources of Arizona. San Francisco: A. L. Bancroft and Company, 1884.

Hughes, Thomas P. Networks of Power, Electrification in Western Society, 1880-1930. Baltimore: The Johns Hopkins University Press, 1983.

Lampen, Dorothy. Economic and Social Aspects of Federal Reclamation. Reprint. New York: Arno Press, 1979.

Lee, Lawrence. Reclaiming the American West: An Historiography and Guide. Santa Barbara, California: ABC-CLIO, 1980.

Luckingham, Bradford. The Urban Southwest, A Profile History of Albuquerque, El Paso, Phoenix, Tucson. El Paso, Texas: Western Press: 1982.

McClintock, James. Arizona. Chicago: S. J. Clark Publishing Co., 1906.

Morris, Richard B. ed., Encyclopaedia of American History. 6th ed. New York: Harper and Row, 1982.

Myers, William A. Iron Men and Copper Wires. Glendale, California: Trans-Anglo Books, 1984.

Outland, Charles F. Man-Made Disaster, The Story of St. Francis Disaster. Glendale, California: The Arthur H. Clark Company, 1963.

Passer, Harold C. The Electrical Manufacturers, 1875-1900. Cambridge: Harvard University Press, 1953.

Pelz, Richard K., ed., Federal Reclamation and Related Laws Annotated. 2 vols. Washington D. C.: Government Printing Office, 1972.

Schuyler, James Dix. Reservoirs for Irrigation, Water Power and Domestic Water-Supply. 1st ed. New York: John Wiley and Sons, 1905.

Sloan, Richard E. History of Arizona. Phoenix: Record Publishing Co., 1930.

Smith, Karen L. The Magnificent Experiment: Building the Salt River Reclamation Project, 1890-1917. Tucson: The University of Arizona Press, 1986.

Smith, Norman. A History of Dams. Secaucus, New Jersey: The Citadel Press, 1972.

Taming of the Salt. Phoenix: Salt River Project, 1979.

Trimble, Marshall. Arizona, A Panoramic History of a Frontier State. Garden City, New York: Doubleday, 1977.

Tuck, Frank. Stories of Arizona Copper Mines. Phoenix: Arizona Department of Mineral Resources, 1957.

Walker, Henry P. and Bufkin, Don. Historical Atlas of Arizona. Norman: University of Oklahoma Press, 1979.

Wegmann, Edward. The Design and Construction of Dams. 8th ed. New York: John Wiley and Sons, 1927.

Zarbin, Earl. Roosevelt Dam: A History to 1911. Phoenix: Salt River Project, 1984.